THE
AMERICAN
SURGEON

Vol. 23, No. 8 August, 1957

PRESENT STATUS OF THE SURGICAL TREATMENT OF CHRONIC ULCERATIVE COLITIS*

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The only proved surgical treatment of the usual type of chronic ulcerative colitis is the formation of an ileac stoma and total proctocolectomy. About 10 years ago, when it became evident that surgical treatment had become materially safer than it had been in the past, considerable interest developed promptly in broadening the indications for surgical treatment and in reducing the number of stages necessary to complete treatment. The problems associated with the ileac stoma also have received much attention during this time. The present discussion will be limited chiefly to these points.

Interest in vagotomy for ulcerative colitis seems to have disappeared almost entirely, and anal ileostomy has been abandoned, at least for inflammatory lesions. The formation of an ileac stoma early in the course of the disease in an effort to influence its progress, and with the idea of ultimately re-establishing intestinal continuity, is no longer practiced. There are unusual cases of ulcerative colitis in which the rectum apparently is uninvolved or is involved only minimally, while more proximal segments are involved extensively. The treatment of choice in such cases is subtotal colectomy and ileosigmoidostomy. The results in some cases are excellent, while in others the rectum becomes involved in time and must be removed. The ultimate result cannot be predicted with complete confidence.

INDICATIONS FOR SURGICAL TREATMENT

The traditional indications for surgical treatment need be mentioned only briefly. They include complications involving the colon such as formation of polyps, strictures and obstruction, perianal infection, perforation, internal or external fistulas, massive hemorrhage and carcinoma. Systemic complications,

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* Presented during the meeting of the Southeastern Surgical Congress, St. Petersburg, Florida, April 1–4, 1957.

particularly arthritis, iritis, extensive cutaneous lesions, hepatitis, and nephritis generally are accepted as at least relative indications. Complications are usually multiple and in many cases the decision to advise surgical treatment is not difficult. In other cases, in which complications have developed but in which they are not advanced, the decision to continue with conservative treatment is more difficult. This is true particularly if the patient is remaining well clinically in spite of the complications. It is most difficult to advise surgical treatment if the patient is doing well on nonsurgical or so-called medical treatment, regardless of the appearance of the colon, providing, of course, that carcinoma can be excluded.

Failure to Respond to Nonsurgical Treatment. Failure to respond to nonsurgical treatment and intractable disease, which are more or less synonymous, are accepted by many as perhaps the commonest indications for surgical treatment.[5] The consensus at the Mayo Clinic still is that only rarely should surgical treatment be advised in such cases before complications have developed. In the absence of complications, it is most unusual not to be able to induce a remission by aggressive medical treatment. Similarly, in cases characterized by frequent severe exacerbations which respond poorly to conservative treatment, complications necessitating surgical intervention may be expected in time. There are of course, exceptions, but they are unusual. In only 4 per cent of a series of 125 patients treated surgically at the clinic during the nineteen hundred and forties was intractability the sole surgical indication.[11]

An exception is made occasionally in the case of children who have not developed physically in spite of reasonably good control of symptoms. It is now known, as will be discussed, that carcinoma is particularly likely to develop in patients in whom the disease begins during childhood. This fact should have some influence in the decision to continue or to abandon medical treatment.

Acute Fulminating Disease. It has been known for many years that the formation of an ileac stoma was extremely hazardous in cases of acute fulminating disease. Recently efforts have been made to treat such patients not by ileostomy alone but by ileostomy and subtotal colectomy. It is held that resection of the colon not only removes the source of infection but also stops the loss of fluids, electrolytes, and blood, which may indeed be considerable. Ripstein, who considered failure to induce a remission within 3 weeks as an indication for resection in acute cases, carried out 43 resections to the rectosigmoid with only two deaths.

As in the case of intractability, those of us at the clinic who are concerned with this problem still maintain that surgical treatment is not indicated necessarily because of an acute exacerbation or in cases in which the disease starts with an acute fulminating attack. The condition of the patient should be followed most carefully by surgeon or internist for the development of complications such as perforation or massive hemorrhage which could well necessitate emergency surgical treatment. Otherwise, I believe that the risk of surgical treatment is greater than that of medical treatment. Antibiotics, which are responsible for the increased safety of surgical procedures, also have made conservative treatment of acutely ill patients much more effective. Blood transfusions and the replacement of losses of fluid and electrolytes are integral parts of conservative

treatment. As Bargen has emphasized, an acute attack does not preclude subsequent successful medical treatment. Indeed, in such cases the response to medical treatment often is unusually satisfactory.

Colectomy to Prevent the Development of Cancer. One of the major hazards of prolonged conservative treatment of ulcerative colitis is the ultimate development of cancer of the colon or rectum. It has been estimated that cancer occurs some 30 times as frequently in patients with ulcerative colitis as in the general population of the same age.[2] The majority of hospitals and institutions presenting statistics on this condition reported the occurrence of cancer in from 5 to 10 per cent of cases. It is particularly likely to develop in cases of chronic ulcerative colitis of 10 or more years' duration and in cases in which the disease begins during childhood. Prolonged remissions and even relatively mild disease do not preclude the development of malignant lesions.[13] The problem is made more serious by the fact that cancers of the colon complicating ulcerative colitis usually prove incurable regardless of treatment.

The possibility of the ultimate development of cancer of the colon should unquestionably have some influence on the decision to advise operation. In view of the difficulties still associated with surgical treatment, I do not believe that the possible development of cancer is in itself a valid reason for advising such treatment. It is a most valid reason for advising removal of the colon and rectum if surgical management is required. As previously implied, the problem is most pertinent in children, and in patients having chronic ulcerative colitis in whom other complications most likely have developed.

In general, it may be stated that surgical treatment at present is far more attractive than it has been in the past. It is being advised currently at the clinic in possibly 12 to 15 per cent of cases, usually because of the traditional surgical complications. In cases in which surgical treatment is necessary, a major effort should be made to prepare the patient psychologically for the ileac stoma. The stoma will prove far more acceptable if the symptoms of the colitis are severe. In a sense, one disease is being substituted for another; and if the symptoms of colitis have been sufficiently serious, the stoma, in spite of its complications, will prove a welcome exchange for the colitis. For the same reason, the formation of a stoma early in the course of the disease may be most inadvisable.

SURGICAL PROCEDURES

The earlier practice of completing the surgical treatment in the three stages of ileostomy, abdominal colectomy and combined abdominoperineal resection has been almost completely abandoned, except in the treatment of unusually debilitated patients. At present a two stage procedure is probably the most widely employed. Either the stoma is established at the first operation and the colon and rectum removed subsequently, or the abdominal colon is resected at the same time that the stoma is formed, and the rectum is removed subsequently. If the former method is chosen, the subsequent resection of the colon and rectum may be made quite difficult technically by the gain in weight which usually occurs after the formation of the stoma.

The two stage procedures were so well tolerated by patients that at some in-

stitutions, including the clinic, the logical extension of surgical treatment to single stage ileostomy and total proctocolectomy was ultimately made. During the 8 year period from 1948 through 1955, 60 patients were so treated at the clinic with three hospital deaths, one each resulting from cardiac arrest, perforation of the terminal ileum, and inanition and debility. In none of the 3 patients could death be attributed directly to the magnitude of the procedure. This experience with single stage procedures has been so gratifying that I believe that in patients of average risk it is at present the procedure of choice. The decision to complete the entire treatment in one stage need not be made before operation. If resection of the colon is started from the right side it may be terminated at any time if the condition of the patient deteriorates. In practice, the contracted and shortened abdominal colon is so easily resected that this much of the procedure is completed routinely. At this point the decision is made to continue with resection of the rectum or to terminate the procedure with the formation of the stoma.

Resection of the rectum is greatly facilitated, shock is decreased, and healing of the posterior incision considerably hastened if the levator muscles and sphincter are preserved, as suggested by Fallis and Barron. It is not difficult to complete the entire procedure from within the abdomen. Should exposure of the lower portion of the rectum prove difficult, the bowel may be divided above the levators, the abdomen may be closed, and the remaining portion of the rectum may be removed through a circular incison around the anus. A lower left rectus incision of adequate length is employed, thereby avoiding any scarring except for that of the stoma in the right lower quadrant.

Reasonable judgment must obviously be exercised with respect to the extent of the surgical procedure. Ileostomy only still has a place, notably in the treatment of extremely debilitated patients. Similarly, there are unquestionably cases in which resection of the rectum should be postponed. To allow patients to become extremely debilitated before resorting to surgical treatment is a most serious if not fatal error in judgment.

COMPLICATIONS AND COURSE AFTER FORMATION OF AN ILEAC STOMA

The conservatism expressed in the present paper with respect to broadening the indications for surgical treatment is based wholly on continued dissatisfaction with ileac stomas. The fact that a stoma is necessary is in itself the major disadvantage of surgical treatment. It is not possible at the present time to assure the patient that a satisfactory stoma will ever be achieved, or that complications will not develop in time regardless of how satisfactory the stoma may be at the moment.

Sholl and I recently reviewed the course of 113 patients who survived the immediate postoperative period. Each patient had an ileac stoma and the majority also had undergone partial colectomy or total proctocolectomy. The results of the study are shown in the table. In spite of the fact that the surgical procedures were carried out by surgeons with considerable experience in the field, complications involving the stoma occurred in more than 49 per cent of

TABLE 1

Results after ileostomy for chronic ulcerative colitis: 1948–1952 follow-up 6 to 72 months

	Patients	
	Number	Per cent
No complications	57	50
Temporary dysfunction of stoma	25	22
Stoma unsatisfactory, no new stoma	4	4
Stoma sacrificed, new stoma		
Ultimate stoma satisfactory	13	12
Ultimate stoma unsatisfactory	14	12
Total	113	100

the patients. A satisfactory stoma was achieved in about 70 per cent of patients without further surgical procedures or with only minor plastic procedures. In more than 20 per cent of them, however, the original stoma had to be sacrificed and a new stoma established. Of greater importance, a satisfactory stoma had not been achieved during a follow-up period of 6 months to 6 years in 12 per cent of the patients. It is probable that a stoma which functions reasonably well can be achieved in some of this group. It is also certain that complications will continue to develop in the group as a whole.

PREVENTION OF STOMAL COMPLICATIONS

Some progress has been made in preventing certain stomal complications. The syndrome of excessive loss of fluid from the ileostomy associated with abdominal cramping, usually called "ileostomy dysfunction," is now known to result from partial obstruction of the protruding ileum. The obstruction, which may be mild or severe, is produced by the tendency of the end of the ileum to contract, by edema, and by the formation of granulation tissue on the serosa of the bowel. It is temporary and disappears with maturation of the stoma, to employ the term commonly used by Turnbull and Crile. They pointed out that the process whereby the stoma achieves its final form can be speeded greatly by covering the serosa with turned-back mucosa. The same result is achieved in Brooke's ileostomy by turning back the whole thickness of the intestinal wall. The application of a skin graft also will prevent temporary early obstruction, cutaneous irritation, excoriation and prolapse.

In the usual form of ulcerative colitis, the inflammatory process involves the ileum in about 30 per cent of cases.[9] The terminal portion of the ileum may be involved for a distance of 30 to 40 cm. If involved ileum is employed to form the stoma, complications such as stricture, abscess, fistula, or hemorrhage are likely to develop. Microscopic examination of the cut end of the ileum by means of fresh-frozen sections is a wise precaution to insure that the ileum has been divided above the involved region.

Skin-Grafted Ileac Stoma. Skin-grafted stomas, described originally by Dragstedt and associates in 1941, differ from stomas of the usual type only in that a

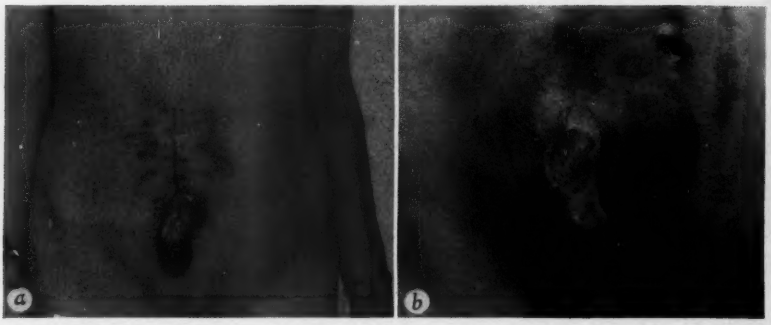

FIG. 1. Skin-grafted ileostomy. *a*. Stoma 11 weeks after operation; *b*, same stoma 7 years later. Excoriation of the skin is absent. The stoma has changed little during the 7 year period.

segment of ileum 6 to 8 cm. in length is brought out beyond the level of the skin of the abdominal wall. The protruding bowel is then covered with a split-thickness graft. The graft must extend from the skin to the tip of the stoma in an unbroken sheet and should be quite thick to withstand the trauma of the appliance (fig. 1). The grafted ileum is held in position by moist gauze fluffs for 4 or 5 days when all dressings are removed and a temporary appliance fitted. The technical aspects have been discussed in detail previously.[4, 12]

The long skin-grafted stoma was devised, of course, to act as a spigot to deliver the ileal contents directly into the ileostomy appliance. The stoma has proved admirable for the purpose. Excoriation of skin is avoided completely and appliances of the adhesive type are neither necessary nor advisable. The difficulties of providing a flat, unscarred area of skin to which the appliance may be cemented, and of contact dermatitis resulting from the appliance or the cement are avoided completely. The skin-grafted stoma, in addition, has largely solved the problems of prolapse and retraction which do not occur with stomas that are more than 5 to 6 cm. in length.

I am still at a loss to explain why skin-grafted stomas have not been more widely accepted. In addition to preventing prolapse and skin excoriation, in my experience and in that of patients who have had stomas of both types, skin-grafted stomas are far more easily managed than stomas of the usual type. Covering the protruding ileum with a graft adds nothing to the risk of the procedure since the graft is applied after the surgical procedure has been completed.

Several complications unique to skin-grafted stomas have been encountered. The graft has failed because of infection in 2 to 3 per cent of cases. Late ulceration of the skin necessitating sacrifice of the stoma has occurred in one case. In 2 cases, condylomatous warts associated with marked inflammatory thickening of the bowel have developed. In both cases the process ultimately progressed to the point of obstruction and new stomas were necessary. I have been somewhat fearful that similar changes would develop ultimately in other cases. So far, however, in an experience with more than 100 such stomas during a 10 year period, no other cases have been observed.

Comment. While major advances have been made in preventing complications arising in the portion of bowel protruding beyond the level of the skin, little progress has been made in the management of complications arising in the abdominal wall or within the abdomen. Obstruction within the abdominal wall or abscesses and fistulas may be expected in perhaps 10 per cent of cases, if the experience at the clinic is typical. The complications are serious and usually necessitate sacrifice of the original stoma and formation of a second stoma. The most important of the intra-abdominal complications is obstruction resulting from adhesions or from volvulus. Such obstructions occur most commonly immediately after operation but they may occur at any time. The decision to proceed with surgical treatment of the obstruction is difficult since patients with ileostomies usually have periodic episodes of obstruction which respond to conservative measures.

It has been proposed that intra-abdominal obstruction can be prevented by suturing the terminal portion of the mesentery to the parietal peritoneum. Garlock and Kirschner have proposed more recently that the terminal part of the remaining ileum should be plicated after the manner of Noble. Suturing of the mesentery to the parietal peritoneum has been done more or less routinely for some years and is not adequate to prevent either volvulus or adhesive obstruction. It is still too early to judge the success of Garlock's proposal. However, the Noble plication has not been widely accepted as a method of preventing obstruction of the small bowel.

SUMMARY

The risk of surgical treatment of ulcerative colitis is at present not materially greater than that of major colonic surgery for other conditions. The entire surgical procedure of ileostomy and total proctocolectomy may be completed at one time, provided that the patient is not unusually debilitated. The success of treatment depends entirely on the establishment of a satisfactory ileac stoma. Major stomal complications occur in at least 20 per cent of cases, while in possibly 10 per cent of cases, a satisfactory stoma is never achieved. While progress has been made in preventing complications arising in the ileum beyond the abdominal wall, those affecting the bowel within the abdomen and in the abdominal wall remain largely unpreventable.

Because of the stoma and the complications associated with it, the surgical treatment of ulcerative colitis still is not satisfactory. Some broadening of the indications for surgical treatment seems reasonable. However, until the remaining difficulties associated with the stoma can be prevented more certainly, surgical treatment should be limited largely to patients in whom complications necessitating such treatment have developed.

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JEJUNAL DIVERTICULA: A REAPPRAISAL OF ITS IMPORTANCE AND REPORT OF THREE CASES

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INTRODUCTION

Jejunal diverticula are more frequently encountered, not only at necropsy, but at the operating table as well, and are now recognized as giving rise to abdominal symptoms and complications necessitating definitive surgery. The purpose of this paper is to re-evaluate the nature of this lesion, its complications, and its importance in geriatric surgery to which all surgeons are being more frequently exposed.

INCIDENCE

According to Phillips,[10] jejunal diverticula were first described by Sir Astley Cooper in 1844. In 1869, Klebs[9] described the association of diverticula with the point of entrance of small arteries. By insufflation, Rosedale and Lawrence[13] demonstrated 4 cases in 300 consecutive autopsies, an incidence of 1.3 per cent. Rankin and Martin[11] reported an incidence of 0.3 per cent by radiologic studies. Gordinier and Sampson[8] were the first observers to see jejunal diverticula at operation. Case[4] reported the first case of diverticulosis of the jejunum in which the diagnosis was made by roentgenogram. In our institution, 4 cases of jejunal diverticula have been seen at autopsy in the last 2 years, representing an incidence of 1.5 per cent. According to Baskin[1], this condition usually occurs in the older age group, the average age being 60 to 69, and affects males twice as commonly as females. Verster[14] in 1937 described a case in a female aged 21 and Benson and associates described a case in a child age 13. It is thought that there is probably a higher incidence in the general population than reports indicate.

MORBID ANATOMY

Jejunal diverticula are most frequently multiple, several dozen being the rule, although in any individual the number may be one, few or many. They are located along the mesenteric border and bulge to one side or the other of the mesentery. The diverticula are most common in the proximal portion of the jejunum, decreasing in number distally and becoming quite uncommon in the lower portion of the small intestine. The diverticula vary greatly in size ranging from a few millimeters up to several centimeters, the majority varying between 1.0 and 4.0 cm. (fig. 1). Usually, the ostia are wide and their lumina contain the usual small bowel fluids; rarely, however, the ostia may be pin point and these diverticula may then contain an enterolith. Diverticula are acquired and

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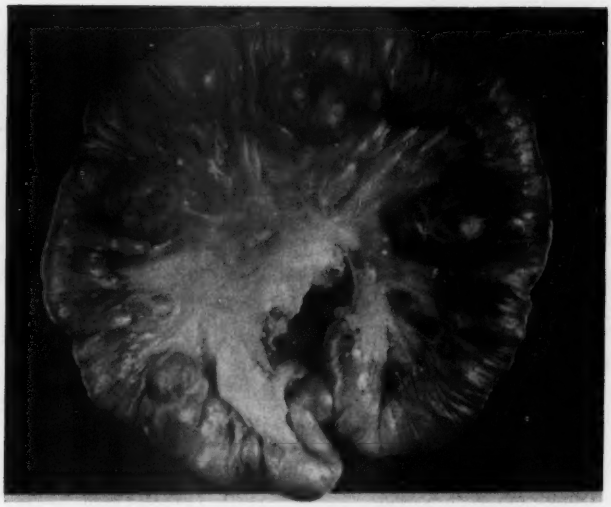

FIG. 1 Segment of jejunum showing numerous diverticula bulging to one side of the mesentery.

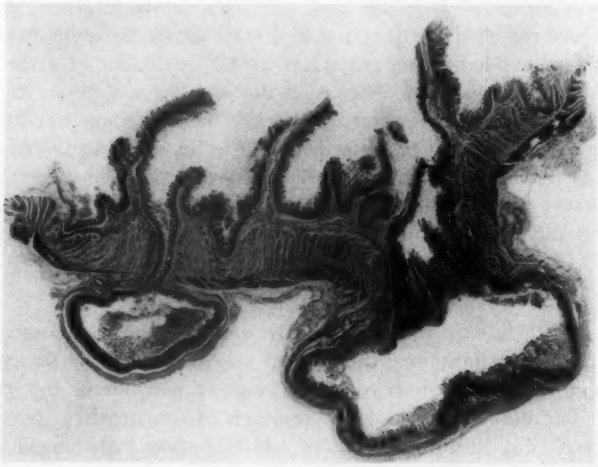

FIG. 2 Gomori trichrome × 3. Photomicrograph of 2 jejunal diverticula showing thinning of longitudinal muscle and hypertrophy of the circular muscle. The diverticula are composed only of mucous membrane and serosa.

arise as herniations between the fibers of the muscularis propria which are frequently hypertrophied. The walls microscopically are seen to be composed of mucous membrane covered by serosa (fig. 2). Fraser[7] stressed the deficiency of the longitudinal muscle on the mesenteric side of the jejunum. Butler,[3] on the other hand, stressed the importance of arteriosclerosis of the mesenteric vessels

acting by traction on the distended bowel. Rosedale[12] took exception to the latter view arguing against arteriosclerosis and stated that it was not seen in all cases, and did not explain those occurring in younger individuals. Rosedale and Lawrence,[13] and Edwards[6] emphasized irregular peristalsis acting to produce increased tension within a segment of bowel between two segments in tonic contraction. Edwards also pointed to the muscular hypertrophy of the jejunum as evidence of the above. From a study of material available to us, thinning of the longitudinal muscle was observed and the thinner portions were frequently at the site of the diverticula. In addition, the circular muscle was not infrequently hypertrophied. It would seem reasonable that actually many factors are interrelated and that thinning of the longitudinal muscle, hypertrophy of the circular muscle, increased pressure due to tonic contractions, and inherent weakness of the bowel at the site of vessel penetration of the muscularis on the mesenteric side, all have some varying degree of importance in the pathogenesis of any individual example.

In the 4 patients with jejunal diverticula autopsied at this institution in the past 2 years, there were associated diverticula of the colon in all 4; in 2, there were diverticula of the duodenum; and in one there were diverticula in the distal portion of the ileum of non-Meckelian types, and essentially similar to those seen in the jejunum.

CLINICAL MANIFESTATIONS

Baskin[1] reported that 61 per cent of jejunal diverticula are asymptomatic. Over a quarter of his patients presented gaseous dyspepsia and/or vague abdominal discomfort. Complications occurred in 10 per cent of his patients. Jejunal diverticula as the cause of dyspepsia and abdominal discomfort is obviously difficult to evaluate and is a diagnosis predominately made by exclusion. Complications of this disease are inflammation, volvulus, bleeding, obstruction and perforation. Acute obstruction may be secondary to adhesions caused by inflammation. Watson[15] in 1924 and Christ[5] in 1932 reported intestinal obstruction secondary to enteroliths which may encroach on the lumen of the bowel producing partial or complete intestinal obstruction. They may become dislodged and produce obstruction lower down in the gastrointestinal tract, where the diameter of the ileum narrows. Volvulus usually occurs secondary to interlocking of adjacent diverticula. Bleeding may be present either as acute massive intestinal hemorrhage or as an hypochromic microcytic anemia secondary to chronic blood loss. Perforation leads to the signs of an acute surgical condition within the abdomen simulating that of acute appendicitis, perforated sigmoidal diverticulitis or more rarely a perforated peptic ulcer. Flat and upright x-ray films of the abdomen may demonstrate free air under the diaphragm. Serial barium studies may outline pockets in the small intestinal pattern in which residual barium remains, giving a clue to the diagnosis.

CASE REPORTS

Case 1. B. S., a 76 year old white woman, was admitted to the hospital on Sept. 7, 1955 complaining of severe abdominal pain, nausea and vomiting. About 24 hours prior to admission the patient began to have nausea and severe abdominal pain particularly in the um-

bilical region. Upon awakening on the day of admission, the patient again had severe abdominal pain and vomited. She had a bowel movement containing a small amount of bright red blood thought to be due to hemorrhoids on the day prior to admission.

The past history revealed a cholecystectomy 10 years ago and review of the old chart indicated that her appendix had not been removed. During the past 8 years, the patient had had severe headaches, dizziness and several minor cerebral vascular accidents.

On admission, physical examination revealed an elderly white woman who appeared acutely ill, moderately dehydrated and somewhat disoriented. The important physical findings were confined to the abdomen. There was marked tenderness over the antire lower abdomen but most marked on the right side. There was considerable muscle guarding almost to rigidity over the lower abdomen and extending up to the right upper quadrant. Rebound was apparent over the entire abdomen. Rectal examination was negative. Temperature on admission was 101.8 F.

The white blood cell count was 9350 per cu. mm. with 91 per cent polys, red blood cell count was 4,500,000, hemoglobin 80 per cent. The urine revealed 1 + albumin, negative sugar and acetone, 4–5 red blood cells and 6–8 white blood cells per high power field. Serology was negative. Roentgenogram of the abdomen was negative for intestinal obstruction and free air.

It was thought the patient had a perforated appendix and an exploratory laparotomy was performed on the day of admission. Peritonitis was diffuse throughout the abdomen. The appendix appeared normal. On further exploration, the source of the peritonitis was found to be a perforated diverticulum of the jejunum subsequently sealed by the acute inflammatory exudate. Numerous diverticula were present in the jejunum and there were a few in the sigmoid. A Miller-Abbott tube which had been passed prior to surgery was present in the small intestine at the completion of the operation. The abdomen was drained and closed.

The patient had a very stormy postoperative course, being disoriented for the greater part of a week and having a temperature up to 103 F. She was treated with intestinal suction, penicillin, streptomycin, intravenous aureomycin and parenteral fluids and vitamins. Her electrolytes were kept in good balance. After a week, the temperature returned to normal, the signs of peritonitis disappeared, and the patient began to have normal bowel movements. Anorexia persisted and tube feedings were begun on Sept. 13, following which the patient improved remarkably; her mental confusion cleared and her appetite improved. The patient then ambulated well and her wound healed without infection. She was discharged on Sept. 21, 1955, 14 days following her admission.

Case 2. A. B., a 76 year old white man was admitted to Menorah Medical Center on May 24, 1955 with a chief complaint of acute abdominal pain located in the right hypochondrium of one day's duration. There was no nausea or vomiting. The patient had had loose bowel movements for one week prior to admission without evidence of blood or mucous.

The patient had been in good general health until 1950, when he was admitted to Menorah Medical Center with acute abdominal pain and found to have diverticula of the duodenum and colon. In 1952 following cholecystectomy, the patient noticed weakness and tarry stools and on admission to Menorah Medical Center was found to have a hemoglobin of 8.5 Gm. It was thought that he had bled from the upper gastrointestinal tract and following conservative management roentgenologic examinations showed, in addition to gastric mucosal prolapse, numerous small and large intestinal diverticula.

On this admission the patient's temperature was 104 F.; pulse 80; respirations 24; and blood pressure 106/64. He was well developed, fairly well nourished and appeared acutely ill. Physical signs related to the current illness were primarily abdominal. Tenderness was present over the entire abdomen. Generalized rigidity and marked rebound were noted. The rectal examination was negative. There were no sensory, motor or reflex changes.

The significant laboratory data was as follows: Hemoglobin 13.25 Gm., red blood cells count was 4.8 million, white blood cells count was 3,500 with 43 polys, 30 stabs, 20 lymphs, 5 monos, 2 metamyelocytes. Nonprotein nitrogen was 34. Electrocardiogram was normal. Roentgenogram of the abdomen was negative for free air.

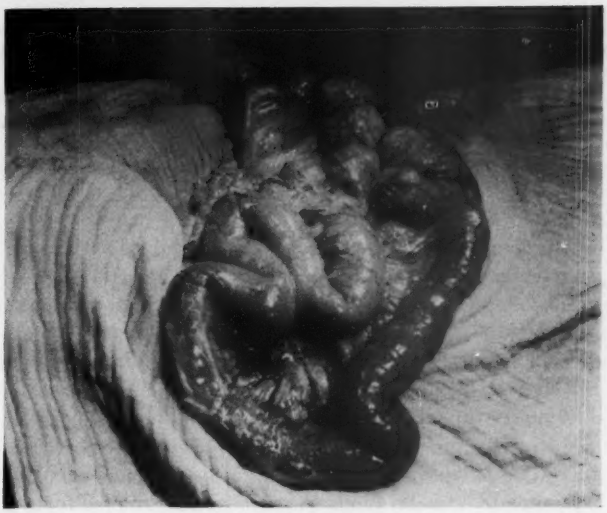

FIG. 3 Operating room photograph of jejunum with numerous diverticula showing plastic exudate of diffuse peritonitis.

The preoperative diagnosis was perforated appendix. At laparotomy the abdominal cavity contained a great deal of turbid fluid which was subsequently cultured and found to contain E. coli. There was a plastic exudate over one loop of ileum with thickening and edema of the loop. More thorough exploration revealed multiple large diverticula of the jejunum extending from the ligament of Treitz to the proximal ileum spaced every 3–4 inches (fig. 3.). One of these had become inflamed, perforated and sealed off. It was thought that it would be impractical to resect such a large portion of the small intestine and because the perforated diverticulum had sealed off, treatment with antibiotics, suction and parenteral fluids was elected. The abdomen was closed and the patient had an uneventful postoperative course, being discharged on the twelfth postoperative day.

Case 3. H. D., a 75 year old white man, was admitted to Menorah Medical Center for the first time on August 5, 1955 with a diagnosis of low small bowel obstruction. The past history revealed that several years prior to admission he had had a gastrointestinal hemorrhage and although an upper gastrointestinal series and a barium enema were negative, the patient was diagnosed and treated for duodenal ulcer. Following this the patient developed a secondary anemia, unexplained, and periodic transfusions were required.

At laparotomy an annular adenocarcinoma of the ileum was found and resected. It was then noted that there were numerous large diverticula in the proximal jejunum. The postoperative course was uneventful and the patient was discharged on August 18, 1955.

He re-entered the hospital on Sept. 9, 1955 with a chief complaint of sudden onset of bleeding from the rectum. Four days prior to admission he developed diarrhea and passed several large dark blood clots. He vomited the usual gastric contents. No blood was present.

The blood pressure was 86/50, pulse 104, respirations 22. The chest was clear to percussion and auscultation. There were no murmurs in the heart and the rhythm was normal sinus. The bowel sounds were active. There was generalized abdominal tenderness but no masses or organs were palpable. Rectal examination revealed a dilated ampulla and the gloved finger showed black stool.

Laboratory findings were: hematocrit 27, hemoglobin 8 Gm., red blood cell count was 3.3 million, white blood cell count was 18,000, polys 49, stabs 36, lymphs 12, monos 3. Urine specific gravity 1.030, albumin 1 plus, acetone negative, red blood cells 2–5, white blood cells 2–4, numerous hyaline and finely granular casts and mucus.

He was treated with multiple blood transfusions, sedatives, opiates, antispasmodics and antacids. In spite of the treatment, he continued to bleed, becoming comatose and died only 5 hours after admission to the hospital.

Autopsy findings were: 1. Extensive intestinal hemorrhage, exact site undetermined, probably from jejunal diverticula. 2. Ileoileostomy, intact (for adenocarcinoma of ileum). 3. Carcinomatosis involving the liver, abdominal and thoracic lymph nodes. 4. Diverticulosis, severe, jejunum. Diverticulosis, mild, sigmoid and second portion of duodenum.

DISCUSSION

Because of the aging population, surgeons and medical men alike are being faced more frequently with the problems incident to the acute surgical abdomen in the aged. The complications of jejunal diverticula which may simulate acute appendicitis, sigmoidal diverticulitis or peptic ulceration, are being more frequently recognized and should be considered in the differential diagnosis. At operation, the surgeon should be certain to explore the entire small intestinal tract and particularly the jejunum lest this condition be overlooked.

It must also be remembered that massive intestinal hemorrhage, although most commonly due to bleeding peptic ulcer is being reported with increasing frequency in jejunal diverticula. When the abdomen is explored for acute massive hemorrhage, particularly in the aged, again the upper small intestinal tract should be carefully examined as a possible source.

It should be emphasized at this point that chronic recurring unexplained anemias may be due to incipient blood loss due to this condition. When the clinician suspects this diagnosis, he may be aided by a careful roentgenologic examination of the small intestinal tract.

Various methods of treatment have been proposed for this condition. In general, medical therapy is the treatment of choice for uncomplicated diverticulosis of the small intestine; surgery is indicated only for the complications. Inversion of the diseased diverticulum is dangerous because it may result in obstruction, ulceration or intussusception. Excision and inversion of the stump may be dangerous because of the friability of the tissue. Segmental resection is indicated where there is segmental involvement of the jejunum and in the case of hemorrhage if the bleeding point can be located. Ordinarily, because the diverticula are multiple, the source of hemorrhage is almost impossible to ascertain. Massive resection is generally contraindicated. It may be advisable to resect the worst portion or to close the abdomen and treat the patient conservatively until the hemorrhage abates. A multiple stage operative resection has been proposed, the first stage consisting of resection of every third diverticulum. Eight weeks later removing one half of the remaining and allowing the intestine to revascularize. The treatment of volvulus and intestinal obstruction is as in any other case; and when indicated, primary resection is performed.

SUMMARY

The importance of jejunal diverticula has been reevaluated with particular emphasis to the acute surgical abdomen of the aged. Hemorrhage, both massive and incipient and perforation are recognized as important complications.

Pathogenesis, clinical features and treatment are reviewed along with presentation of 3 illustrative cases.

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RESPIRATORY ARREST FOLLOWING ADMINISTRATION OF INTRAPERITONEAL NEOMYCIN

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Oral Neomycin is extensively used for intestinal antisepsis in anticipated large bowel surgery. The preoperative preparation of Neomycin combined with Sulfasuxidine and Sulfathalidine is easily administered and more effective than any other antibiotic singly or in combination. Its effectiveness against enterotoxic staphylococci precludes the development of pseudomembraneous enterocolitis as a complication of its use. However, this may be a serious complication of bowel preparation with other antibiotics and not without significant morbidity and mortality.[1, 4, 6]

Oral Neomycin has a wide range of safety, because it is poorly absorbed. The intramuscular preparation is quite toxic and its use is hazardous. It has been demonstrated experimentally that Neomycin placed in the peritoneal cavity is considerably more toxic than is oral administration of the drug.[7, 8] The toxicity of intraperitoneal Neomycin is abetted by previous oral intake.[5] Laboratory assay of different lots of Neomycin has revealed varying toxicity and recent preparations were more toxic than earlier ones.[8]

Although there are few clinical reports of the intraperitoneal use of Neomycin, there is reason to believe that it is frequently used as an irrigating or repository intraperitoneal solution, where fecal contamination is present. In this community, peritoneal lavage with solutions containing antibiotics has been widely used. The peritoneal toilet has been advised by Jenkins[2] in all patients where fecal soilage exists, and also in elective abdominal surgical patients particularly when anastomoses are performed. A solution of Hartmann's, Ringers, or saline solution is used. To each liter is added .5 gram of Streptomycin and ½ to 1 million units of Penicillin, or 500 mg. of Terramycin. Depending upon the amount of contamination present 1–5 liters is used for the lavage. Much of the solution is spilled and aspirated and only a small quantity remains after the viscera have been replaced. Kredel[3] also has reaffirmed the value of intraperitoneal antibiotic solutions in abdominal trauma. Although the cases have not been reviewed, one has a favorable impression of using intraperitoneal antibiotic solutions, when there has been gross or presumed fecal spillage during emergency intestinal tract repair or elective enteric anastomosis.

Poth[4] advises intraperitoneal doses of 2–3 grams of a 1 per cent Neomycin solution adding 1 gram at completion of the operation, for a total of 4 grams. Not all of this remains in the peritoneal cavity since there is spillage and aspiration of the solution during operation.

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A recent report by Pridgen[5] of 4 cases of respiratory arrest following intraperitoneal Neomycin has prompted the authors to report a similar experience. In the case reports by Pridgen, the Neomycin solution used was of small volume and was placed in the peritoneal cavity when abdominal wall closure was begun. Hence very little spillage to the outside is thought to have occurred; and none of the solution was aspirated. Two infants received .5 grams of Neomycin each. Two adults received approximately 3 grams. All developed respiratory arrest. The two infants died. The adults recovered without sequelae.

The cases that we are reporting are interesting in that the dose of intraperitoneal Neomycin was quite excessive. Happily, recovery was complete in each instance.

CASE REPORTS

Case 1. C. W., a 6 year old Negro girl was operated upon on Sept. 26, 1956 because of intestinal obstruction. At operation, the distal ileum and cecum were involved in an internal hernia due to a thick adhesive band. This portion of the bowel was gangrenous and was resected. An ileo-ascending colostomy was performed. Five grams of Neomycin in 20 cc. of saline solution was instilled in the bowel. The peritoneal cavity was lavaged with 2000 cc. of saline solution, after which 5 grams of Neomycin in 20 cc. of saline solution was left in the peritoneal cavity.

During closure of the abdominal wall, spontaneous respirations ceased. The patient's blood pressure and pulse remained normal. The plane of anesthesia deepened. The pupils were widely dilated and the corneal reflex was lost. Oxygen was given by positive pressure. Spontaneous respirations returned after an interval of 15 minutes. Several hours later the child reacted from anesthesia and thereafter the postoperative course was uncomplicated.

Case 2. V. B., a 49 year old white man was admitted to the hospital on Sept. 14, 1956 with large bowel obstruction due to carcinoma of the splenic flexure of the transverse colon. A loop colostomy at the hepatic flexure was performed the day of admission. On September 27 the patient underwent resection of the ascending, transverse, and descending colon, and splenectomy, with ileosigmoidostomy. An open anastomosis was performed.

Preoperatively he received 16 grams of Neomycin orally. In addition 10 grams of Neomycin was instilled in the proximal and distal loops of the colostomy.

There were no complications during the operative procedure. At the completion of the operation, the peritoneum was lavaged with 3000 cc. of Hartman's solution to each liter of which was added one million units of penicillin and .5 Streptomycin. Five grams of Neomycin in a 10 per cent solution was placed in the bowel lumen. Ten grams of Neomycin in 30 cc. of saline solution was then placed in the peritoneal cavity as a repository solution. During closure of the abdominal wall spontaneous respiration ceased. The blood pressure fell from 140/70 to 80/40. The pulse was stable at 64–70 per minute. The temperature was 94 F. The blood pH was 7.15.

The patient had been intubated throughout the procedure. The anesthetic agents included nitrous oxide and oxygen, and pentothal and intravenous Anectine. During the last 30 minutes of anaesthesia he was given ether and oxygen. He received no Anectine during this time. Respirations gradually returned over a period of 5 hours. Throughout this time interval, oxygen was administered via a nonrebreathing apparatus with positive pressure on the chest for expiration. Thereafter, his postoperative course was without incident.

COMMENT

Until the article by Pridgen came to our attention, we had been unable to define the etiology of respiratory arrest in the 2 patients whose cases are re-

ported herein. Since each had received a peritoneal lavage of a large volume of solution, the possibility of sudden hypothermia was entertained. The solutions used for lavage were not prewarmed and considering the site of storage, were probably below room temperature. In the second patient, an individual idiosyncrasy to Anectine was thought to be a contributory factor. However, since respiratory arrest is a manifestation of Neomycin toxicity, the intraperitoneal dose which was given, and which was excessive in each patient, is considered causative.

Pridgen reported a personal communication from Poth as follows: "Acute toxicity manifests itself by respiratory arrest. We have maintained experimental animals for hours by artifical respiration following respiratory arrest induced by intraperitoneal Neomycin."

SUMMARY

Two cases of respiratory arrest following the administration of intraperitoneal Neomycin are reported. This brings to 6 the total number of cases reported in the literature. It is known that oral Neomycin is well tolerated in large doses. Also, it is considered the antibiotic of choice for the preoperative preparation of the large bowel. Previous oral administration of Neomycin enhances the toxicity of the drug when subsequently given intraperitoneally. One should exercise caution when using Neomycin in the peritoneal cavity. The total dose given should not exceed 3 grams of Neomyci in a 1 per cent solution.

This report should not be construed as a condemnation of the use of intraperitoneal antibiotics, particularly Neomycin. Rather it is hoped that knowledge of this serious complication will lead to avoidance of factors which produce it.

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STAPHYLOCOCCAL EMPYEMA IN INFANCY*

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Many aspects relating to infectious involvement of the pleura in infants and children have been changed by the extended availability and widespread usage of potent antibacterial agents. Prior to 1938, the pneumococcus was the most frequent cause of empyema in this age group.[5, 12] More recent reports concerning this subject indicate that the staphylococcus has now become the most frequent offending agent.[1, 5, 6, 9] Whether or not this change in incidence is actual or relative is of little statistical importance. Staphylococcal empyema is a disease that shows a predilection for children under 1 year of age.[2, 7, 12] The organism most frequently cultured from the involved pleura is the staphylococcus aureus, although staphylococcus albus has been isolated from some cases. It is believed that there is a relationship between pigment production and toxicity on one hand and pathogenicity on the other.[2]

PATHOLOGY

The causative organism may reach the lung by way of the respiratory passages or through the blood stream.[2, 4] The latter mechanism of involvement presupposes the existence of a bacteremia resulting from a staphylococcal focus of infection in another area of the body, such as otitis media, pyodermia, osteomyelitis, etc. Some of these blood borne organisms are filtered out and remain in the lung to initiate the infectious process.

Most frequently the avenue of invasion is by way of the trachea, bronchi and lymphatics. The resulting pneumonitis which is believed to precede most cases of staphylococcal empyema may be overwhelming, so as to fatally terminate the process at this stage before extension has occurred. Most patients pursue a more chronic course with the development of pleural involvement. The lung parenchyma becomes studded by multiple abscesses which increase in size as the necrotizing process progresses. Rupture of these "pulmonary furuncles" with discharge of pus into the pleural space may occur, since each pulmonary segment is bounded by a pleural investment. The extent of pleural involvement is determined by the rapidity with which pyothorax occurs, the more slowly developing cases allowing time for walling-off of the involved area by parietal and visceral adhesions.

Direct invasion of the bronchial wall may occur with abscess formation followed by ulceration and perforation. This allows air to escape, and if the abscess cavity already communicates with the pleural space, a pyopneumothorax results. Considerable tension may develop in the thorax due to the presence of a valve-like mechanism which permits air to pass only out of the bronchus.[8] If the con-

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tinuity of the surrounding lung tissue has not been interrupted, increasing tension within the abscess cavity may result in a pneumatocele. These giant air cysts are capable of precipitating the complications which result from altered intrathoracic dynamics.

CLINICAL FEATURES

The clinical course of this condition may be characterized by sudden onset of fever, abdominal distention, diarrhea, anorexia, listlessness, cough and rapid respiration.[4] Severe toxicity and a sudden "turn for the worse" may be manifest by cyanosis, tachycardia and paleness. The entire chain of events may occur in only 24 to 48 hours. High fever may not be a constant finding, especially in infants. Dyspnea, along with intensification of the above symptoms, usually denotes the development of pyopneumothorax. Dullness to percussion with limited expansion of the involved hemithorax may also be demonstrated. Auscultation is usually of little value in the diagnosis of staphylococcal empyema in infants.

Radiographic examination of the chest is of immense value in diagnosis and management. The occurrence of spontaneous pneumothorax, pneumatocele or the combination of diffuse empyema, rapidly changing parenchymal signs and loculated empyema all point toward staphylococcal empyema.[3] Films taken in the erect position are especially important in the early recognition of pyopneumothorax. The presence of air and fluid in the pleural cavity should invariably suggest staphylococcal disease.[5]

The unequivocal establishment of a positive diagnosis must await culture of the staphylococcus from the blood, pleural fluid or lung.[2] Isolation of this organism from the nose or throat is not conclusive evidence, since it has been demonstrated to be present in the nose or throat of 60 per cent of normal infants under 7 days of age.[3, 10]

TREATMENT

The ineffectiveness of antitoxins and bacteriophages in improving the prognosis of staphylococcal infections has been repeatedly demonstrated.[12] Before the advent of antibiotics, the mortality rate for staphylococcal empyema was almost 100 per cent. A recent series, although not large, has been reported in which the mortality rate was zero.[1] Although the prognosis of this condition has been definitely improved by the widespread usage of penicillin and streptomycin, the emergence of resistant strains is apparent. The current availability of many antibiotics of proved value in the treatment of resistant staphylococcal strains has markedly improved the patient's chances for recovery. Erythromycin and chloramphenicol are currently effective in the management of this condition. Culture of empyema fluid with sensitivity studies should, then, be among the early measures taken to control this infection. The importance of re-evaluating sensitivity from time to time must be kept in mind because of the possibility of the development of resistant strains during the course of treatment.

Adequate maintenance of fluid and electrolyte balance is as important here

as in any other severe illness. Oxygen therapy should be readily available, as the borderline pulmonary reserve of these acutely ill infants may precipitate an acute emergency. Transfusion of small amounts of whole blood is a valuable adjunct in treatment.

Even though great reliance is placed upon antibiotics, empyema collections, like loculated pus in any other part of the body, must be drained. Chest films will give early indications of fluid collections with final proof being afforded by the aspirating needle. Not only is the empyema cavity identified, but immediate improvement in the general condition of the patient can be expected. Prompt thoracentesis may be a lifesaving measure in the presence of tension pneumothorax or pneumatocele.

It has become increasingly apparent that the early institution of closed intercostal drainage improves the prognosis and facilitates convalescence.[8] With the ever-present danger of tension pneumothorax, it is quite comforting to know that a functioning intercostal drainage tube is present. This also provides a constant route of egress for fluid collections with elimination of the frequent need for thoracentesis. Resection of a rib segment with insertion of a drainage tube is tolerated remarkably well by the acutely ill infant. This procedure should be done in the operating room under local anesthesia. Although a small bore polyethylene catheter may be used,[8] we prefer a soft rubber catheter, size 14 or 16. Multiple holes are made in that portion of the tube which is to remain within the chest. It is securely fixed to the chest wall and connected to a continuous source of low intensity suction.

Enzymatic debridement with streptokinase and streptodornase has been used with gratifying results.[11] Staphylococcal pus, especially in the late stages of the disease, becomes very thick and is removed from the chest with difficulty. Intrapleural instillation of Varidase is followed by marked thinning of this material, and drainage is greatly facilitated. The enzyme is injected along with an antibiotic, following which the thoracotomy tube is clamped for 1 hour. As the empyema loculi are digested, remaining viable organisms are brought into direct contact with the antibiotic. Expansion of the lung is greatly facilitated by this process. Moderate febrile reaction may be noted, but not of sufficient degree to warrant discontinuing the injections. Decortication is seldom necessary if these principles are utilized.

The following case reports illustrate some of the problems encountered in the management of this disease.

CASE REPORTS*

P. D., a three week old white male, was hospitalized (July 26, 1956) because of cyanosis and labored respirations of one day's duration. Examination revealed an acutely ill infant with rapid, grunting respiration. There was cyanosis, along with abdominal distention and dullness, over the right chest. Roentgenograms revealed pneumonia with pleural effusion involving the right hemithorax (fig. 1). He was treated with systemic antibiotics, oxygen, parenteral fluids and thoracentesis. Thick, yellow pus was removed from the pleural

* These patients were followed by Dr. Blair Batson and Staff, Department of Pediatrics, University of Mississippi Medical Center.

FIG. 1.—P. D. A, Loculated empyema on right side. B, After insertion of drainage tube. C, Satisfactory clearing after 2 months.

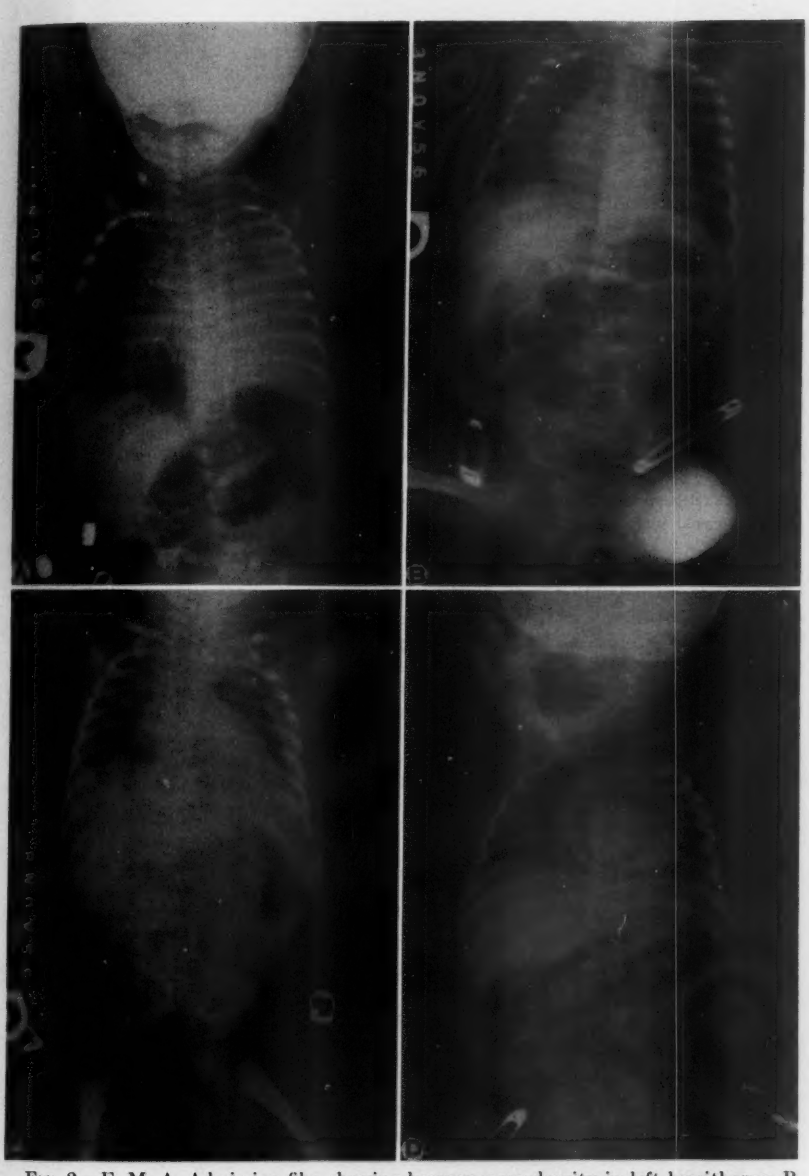

FIG. 2.—E. M. A, Admission film showing homogeneous density in left hemithorax. B, Collapsed lung with pyopneumothorax (3 days later). C, Partial re-expansion of lung with drainage tube in left hemithorax. D, Satisfactory chest film made 1 month after hospital admission.

space, which when cultured yielded staphylococcus aureus. In spite of daily aspiration of the involved chest, he developed tension pneumothorax 4 days after admission, necessitating emergency thoracentesis. Closed thoracotomy tube drainage was instituted (Aug. 8, 1956) with daily injections of antibiotics and Varidase. His improvement was consistent following this procedure, and he was discharged on Sept. 5, 1956. Chest films taken 2 weeks after discharge revealed remarkable thinning of the pleura with complete expansion of the lung.

E. M., a 10 week old Negro female, was hospitalized (Nov. 1, 1956) because of fever, cough and difficulty in breathing. Although labored respiration had been noted for only 24 hours, symptoms indicative of an upper respiratory infection were present for 3 days. Examination revealed an acutely ill infant with a temperature of 97 F., respiration of 90 and pulse of 130. Auscultation revealed a pericardial friction rub with decreased breath sounds over the left hemithorax. Roentgenograms revealed a homogeneous density in the region of the left lung with shift of the heart to the right (fig. 2). Thoracentesis yielded purulent material containing gram positive cocci. Staphylococcus aureus was cultured from this material. Treatment consisted of systemic antibiotics, oxygen, parenteral fluids, and 40 micrograms of Cedilanid. Three days after admission, her general condition appeared much improved and oral nourishment was begun. Chest films at this time revealed partial collapse of the left lung, while this hemithorax was filled with air and fluid. Closed thoracotomy tube drainage was instituted, following which much progress in re-expansion of the lung was noted on November 8. Chest films made on Dec. 3, 1956, after discharge from the hospital, revealed satisfactory improvement.

J. D. R., a 7 week old Negro male, was born at University Hospital, June 17, 1956. His birth weight was 4 lbs. 7 oz., but in spite of prematurity his progress was good until July 2, 1956, when it was noted that he "looked sick", had a grunting cry, and exhibited moderate abdominal distention. Two days later he was found to be in acute respiratory distress. There was dullness over the left chest, along with marked abdominal distention. Thoracentesis yielded a large amount of air and fluid which resembled gastric content. This greatly improved his respiratory difficulties. From the physical signs and roentgenographic findings, the clinical impression favored diaphragmatic hernia, for which exploratory thoracotomy was carried out. This revealed a tension pneumothorax which had resulted from rupture of a small lung abscess. The bronchial opening was closed, following which a thin membrane was removed from the surface of the lung. Staphylococcus aureus was cultured from this material. His course was complicated by the development of osteomyelitis of the eighth rib, but was otherwise uneventful.

CONCLUSIONS

The staphylococcus organism is now the most frequent cause of empyema in infants.

The mortality rate of this condition has undergone marked improvement since the advent of antibiotics.

Serious complications resulting from the sudden occurrence of tension pneumothorax may occur without warning.

Closed thoracotomy drainage is a valuable adjunct in therapy and should be instituted early in the course of the disease.

Pulmonary decortication is seldom indicated in properly managed patients.

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A SECOND LOOK OPERATION FOR QUESTIONABLE NONVIABLE BOWEL: CASE REPORT

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When nonviable bowel has made immediate surgery imperative, and the chance for preoperative intestinal antisepsis is precluded, it is important that intestinal resection and primary anastomosis be minimal.

This is a report of a case of a patient in whom a loop of previously strangulated bowel was allowed to return to the abdominal cavity for a 24 hour period, meanwhile being held by a loop of soft rubber drain, so that it could be found easily and examined for viability.

Mrs. R. L., a 70 year old white woman, was admitted to the Okmulgee City Hospital on May 14, 1955, at 10 p.m., complaining of vomiting and abdominal pain. Physical examination revealed a tender swelling in the left femoral region. Her temperature was 98.8 F., pulse 90 and respirations 25.

Laboratory findings were: erythrocytes 5,310,000 per cu. mm., hemoglobin 97 per cent or 16.4 Gm., leukocytes 26,400 per cu. mm., seg. 75 per cent, Stab. 10 per cent, lymph 12 per cent and Mono. 3 per cent; urinalysis, color amber, specific gravity 1.024, albumin, trace, sugar negative, indican 4 plus and microscopic, negative.

A tentative diagnosis of strangulated femoral hernia, left, was made.

The patient was taken immediately to the operating room, and under local xylocaine 1 per cent anesthesia, an incision was made in the left femoral area. A hernia mass was dissected free, the neck loosened, and the sac opened. It contained a loop of purplish discolored small bowel. The hernia sac contained about 50 cc. of bloody fluid. The strangulated bowel was released from the constricting hernia ring and brought out through a muscle splitting incision 3 inches above the hernia area. It was covered with moist, warm saline packs to be observed after the hernia repair had been accomplished. The peritoneal sac was doubly ligated with cotton, and the hernia was repaired with interrupted cotton sutures.

The damaged bowel was now re-examined for evidence of viability. It remained quite discolored and peristalsis was questionable. Rather than resect, another alternative occurred to me. Why couldn't the injured bowel be allowed to return to the abdomen and be re-examined again in 24 to 48 hours. After reaching such a decision a small opening was made in the mesentery a short distance away from the injured bowel area and a Penrose drain was passed through this opening. The bowel was then returned to the abdominal cavity attached to the Penrose drain loop. The abdominal incision was closed loosely by means of silk mattress sutures with the Penrose drain protruding to enable re-examination of the bowel for viability. The operation consumed approxi-

mately 2 hours. It was done under local anesthesia. At the end of the operation the patient's condition was good.

The immediate postoperative care included a transfusion with 500 cc. of whole blood, penicillin 600,00 units and intravenous fluid therapy, being careful to include only enough saline solution to replace that lost by vomiting the previous day. On the first postoperative day her temperature was 100 F. in the afternoon but her pulse and respirations remained normal. On this same day she was returned to surgery, where the muscle splitting incision was reopened and the contused bowel (found by its Penrose drain attachment) was gently exteriorized. Re-examination revealed that although the bowel was still quite discolored there was no constriction and there was peristaltic activity. The rubber drain loop was removed. A double Penrose drain was inserted and the incision was closed in layers. This second operation was accomplished in about 30 minutes without discomfort to the patient under local xylocaine anesthesia. The first two bowel movements contained considerable dark blood, some of which was either organized blood clot or bowel mucous membrane which had sloughed off. By the third postoperative day the patient was expelling flatus and had a good appetite. She was discharged from the hospital on June 3, 1955 on her nineteenth postoperative day.

She has been seen several times since her discharge from the hospital. The femoral hernia repair has remained firm, and she has regained her normal health.

DISCUSSION AND SUMMARY

A second look type of strangulated hernia operation avoided an unnecessary bowel resection. It is worth noting that this elderly, malnourished patient did well under the use of local anesthesia where general anesthesia might have increased her morbidity.

In experimental studies on dogs Cohn, Langford and Rives[1] demonstrated that a certain amount of devascularized bowel, when protected by antibiotic therapy, might slough off its mucosae, but the muscularis being able to withstand greater trauma might remain intact allowing the mucosae to regenerate.

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CONCURRENT LIVER BIOPSY AND CHOLECYSTECTOMY

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To my knowledge no similar study of concurrent liver biopsies and cholecystectomies has been undertaken, with the hope to prognostically lead to a better understanding of the so-called 'postcholecystectomy syndrome', to anticipate hepatic coma, and to assess the condition of the liver without any preliminary preoperative dietary preparation of the patient.

Mateer, Hartman and others[2] in 1948, attempted a correlation of liver biopsies and the various liver function tests, on the material obtained from cases of cholecystectomy and peptic ulcer laparotomy. The biopsy material in their study, was obtained chiefly with wedge resection as contrasted with needle biopsy. They had only 6 per cent and 7 per cent respectively of histologically normal liver in the entire series, on a basis of comparison with a normal liver of a normal child 10 years of age.

This does not seem to be a valid comparison. The average age of the patients in their series was 52 years, at which time there are considerable subcapsular portal changes in most individuals. This, then, detracts from the use of material obtained from wedge resection, for the evaluation of liver function and correlative changes associated with gallbladder disease.

This study consists of 282 cases of cholecystectomy with concurrent liver biopsy. There were 62 male and 220 female patients with the following age distribution:

	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90
M	1	0	4	5	14	23	7	6	2
F	0	3	29	41	53	49	30	12	1

It was assumed that perhaps gallbladder disease was associated with various forms of liver damage. Anatomically there is a close and continuous relation of the blood and lymphatic systems of the liver and the extrahepatic biliary system. By conjecture, a metabolic disease or infection of the extra hepatic duct system may be mirrored pathologically in the liver. This may result from absorption of products or direct extension of infection, and result in temporary or permanent liver damage. Liver biopsy is an accepted method to study this organ.

All the material presented here, was studied by one pathologist, R. J. Ritterhoff, M.D., so that a more or less uniform standardization is obtained in the study of the liver slides.

Presented during the St. Petersburg Assembly of The Southeastern Surgical Congress, St. Petersburg, Florida, April 1–4, 1957.

The liver biopsy is always taken with a Vim-Silverman needle, and the specimen is obtained from the central portion of the right lobe of the liver and immediately placed in formalin. Biopsies of the surface or edge of the liver are not included in this study.

All of the gallbladders except 5 contained gallstones. All of the patients clinically demonstrated the symptoms and findings of gallbladder disease, including x-ray studies. In none of them was there clinical data to suspect concomitant liver disease. The youngest patient was a 6 year old boy with gallstones and a perforated gallbladder, and the oldest an 89 year old white woman with gallstones.

The incidence of gallstones in North America varies from 3 per cent to 20 per cent of adult necropsy findings, and ranging from 1.6 to 5 times more common in the females. In surgical material the ratio is 8 females to 1 male. In this study the ratio is about 3.5 females to 1 male. At autopsy 54 per cent of females and 25 per cent of males over 70 years of age show gallstones. At St. Elizabeth Hospital, Covington, Ky. 20 per cent of adult necropsies revealed gallstones. These percentages of gallstones found at necropsy vary with the enthusiasm of the individual pathologist, whether he looks for and records the presence or absence of gallstones. In all probability the incidence of gallstones is the same in North America, both in cirrhotic and noncirrhotic patients.

Carcinoma of the gallbladder accounts for from 2 per cent to 6 per cent of all cancer found at necropsy. There were 6500 deaths from carcinoma of the gallbladder in 1936 in the U. S. A.

Ulin[1] had 14 cases of gallbladder carcinoma in 500 cholecystectomies, or about 2.8 per cent. One of every 36 patients who had cholecystectomies showed evidence of gallbladder carcinoma, with a ratio of 4 females to 1 male. In this series there were 8 carcinomas, 4 males and 4 females, or about 1 carcinoma in every 35 cholecystectomies.

It would be well to give a few definitions of some of the terms used in this paper.

Intrahepatic pericholangitis or pericholangeolitis is a leukocytic cellular infiltrate in the periductal areas, even though collateral evidence of active cholangitis is lacking. This may lead to pericholangitic hepatitis, fibrosis or cirrhosis. Since only one patient showed an associated acute intrahepatic cholangitis, the concept of ascending infection as a cause for the more frequently found state of intrahepatic pericholangitis is not well supported, and the condition of intrahepatic pericholangitis may represent a reaction to the products of inflammation.

There were 44 cases or 15.6 per cent of the series. Eight patients were males or 12.9 per cent and 36 females or 16.3 per cent.

Cirrhosis is a generic term used clinically and pathologically, and is inclusive of the following types, nutritional, posthepatitic, postnecrotic, biliary, pigmentary, various granulomatous infections, and the so-called cardiac cirrhosis. Clinically, many of these are indistinguishable, and pathologically, there is a considerable overlap in the histology leading to variations in opinions. An indi-

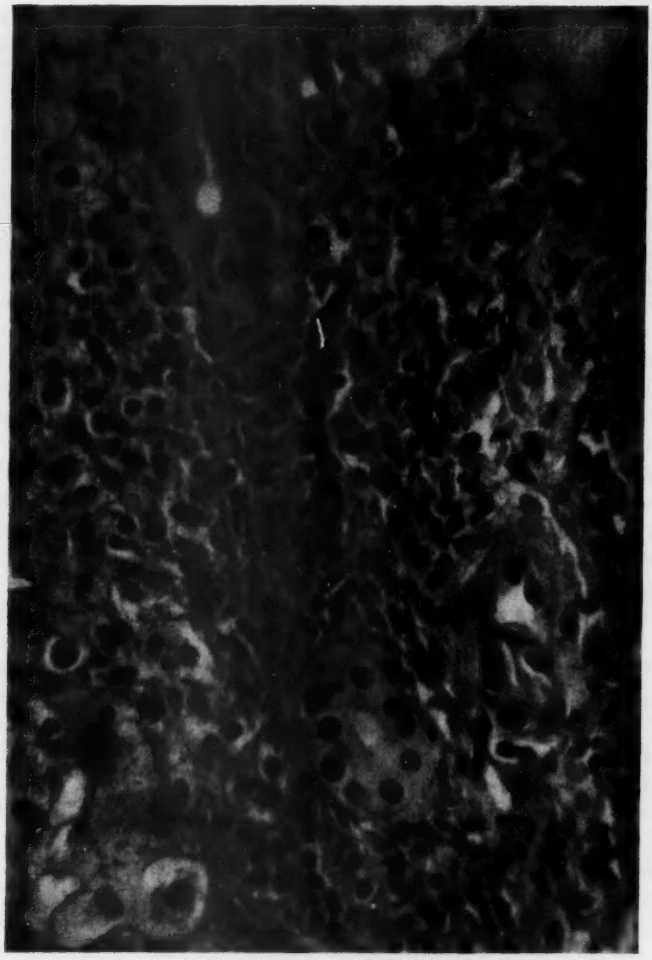

FIG. 1 Acute and chronic intrahepatic pericholangitis

vidual may be suffering from a number of causes which can produce cirrhosis, leading to difficulty in definitive interpretation. Biliary cirrhosis is probably an interplay of repeated attacks of bile stasis, cellular degeneration, necrosis and ascending infections. Although the patients in this series were classified as to type of cirrhosis, they will be considered as a group, the fibrous tissue response to injury. The vast majority of these patients had minimal to moderate fibrosis.

There were 29 cases of "cirrhosis" or 10.2 per cent, male 7 patients or 11.3 per cent and 22 females or 10 per cent.

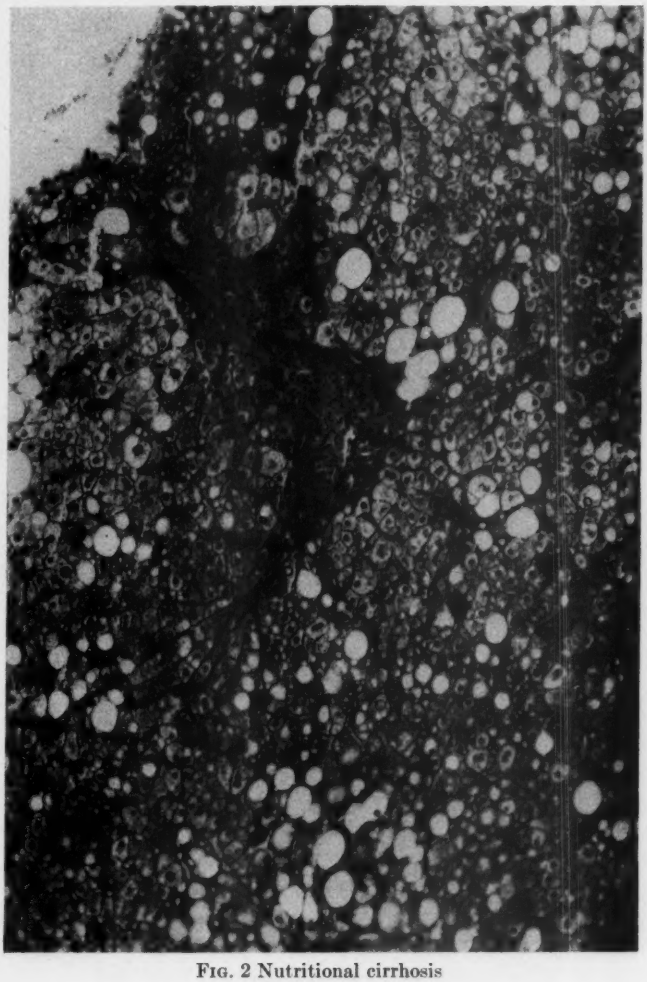

FIG. 2 Nutritional cirrhosis

Hepatitis is a hepatocellular degeneration often progressing to necrosis, accompanied by an inflammatory reaction and in later stages by lobular collapse, regeneration and variable fibrosis.

This was encountered in 3 patients, 1 male and 2 females or 1.06 per cent.

Hepatosis is a hepatocellular degeneration not accompanied by necrosis or inflammatory reaction.

Ten patients or 3.5 per cent presented this finding, 4 were males or 6.2 per cent and 6 were females or 2.7 per cent.

The other terms need no definition.

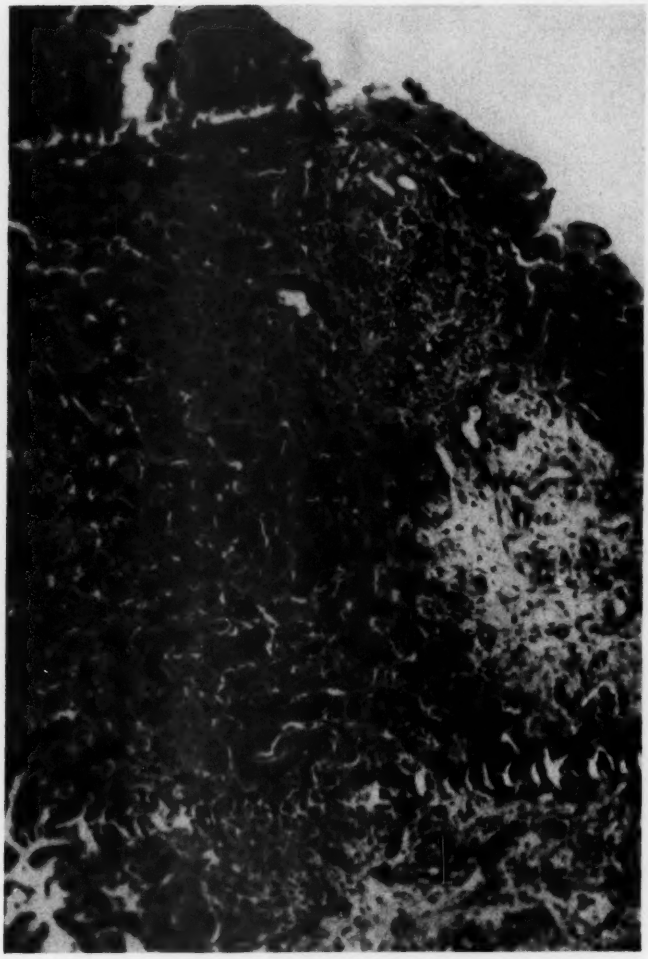

FIG. 3 Biliary cirrhosis

Biliary stasis was encountered in 9 patients or 3.1 per cent. There were 3 males or 4.8 per cent and 6 females or 2.7 per cent.

Fatty infiltration was demonstrated in 16 patients or 5.6 per cent, there being 9 males or 14.5 per cent and 7 females or 3.2 per cent.

There were 7 deaths during the initial hospital stay for a rate of 2.47 per cent. Males 3 or 4.8 per cent and females 4 or 1.8 per cent. An analysis of the deaths revealed 4 patients having had intrahepatic pericholangitis, one with an associated bile stasis. One developed acute pancreatitis on the third postoperative day,

FIG. 4 Bile duct obstruction with bile duct triad

with no liver disease shown on biopsy. The other 2 patients revealed no liver disease. None of the deaths could be attributed to liver damage.

SUMMARY

From this study it is apparent that an appreciable number of individuals with gallbladder disease have either related or independent liver disease, usually of a mild degree.

The presence of these changes in the liver in no way affected the postoperative course as to length of stay, complications, or death.

The deaths that occurred are ascribable to the severity of the gallbladder disease or other causes, nonhepatic.

The necessity of special preoperative preparation is questioned in those individuals of apparent fair nutrition. Patients with moderate fatty infiltration showed no particular difficulty.

Five of the 16 patients who had fatty infiltration developed clinical evidence of gout.

As pointed out, individuals may be suffering with multiple organ difficulties of different etiology, as in the 3 cases of hepatitis associated with cholecystitis with stones. Individuals with hepatitis will and must need be operated upon at times.

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CHOLEDOCHOTOMY AND CHOLANGIOGRAPHY

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The discovery of a stone in the common duct after an operation on the biliary tract, is cause for the greatest embarrassment and frustration to the operating surgeon. He must admit, at least to himself and sometimes to his patient, that his operation has been incomplete and that his patient may continue to be ill because of this fact. Circumstances may make this situation excusable but frequently the stone remains in the duct either because the surgeon did not suspect that it was there in the first place or because his exploration was inadequate. It may be some comfort to read in the literature the experiences of our most distinguished surgeons in this field for it seems that all have had similar failures in a varying percentage of cases. Of the many series reported, the majority conclude that between 10 and 20 per cent of patients who have choledocholithotomy will show postoperative evidence of overlooked stones. Although not all of these will require a second operation, these figures do mean that 1 or 2 patients out of every 10 who have an operation for common duct stones will have an unsatisfactory result due to an incomplete operation. This fact only serves to emphasize the difficulties in avoiding such an error and the necessity for using all means at our disposal to do a more complete job in every case.

Only in the last few years has cholangiography been used with sufficient frequency to make possible its evaluation on a large scale. Those surgeons who have tried cholangiography only to give it up have usually been discouraged by the technical difficulties and the lack of reliability of the interpretation of the cholangiograms. It is well to remember that similar objections and difficulties were encountered for years during the early days of many special x-ray procedures, such as cholecystography and pyelography. Cholecystograms and gastrointestinal series are now universally accepted in spite of the many false negative and false positive reports from even the best roentgenologists. As our experience, both individually and collectively, with operative cholangiography increases, we will learn how to get more uniformly good films and have more uniformly reliable interpretations. Ferris and Weber, reporting 200 operative cholangiograms, have 15 failures due to faulty technic in their first 25 cases. However in the remaining 185 cases there were no technical failures and valuable information was gained from 183 of the cholangiograms, there being only one false negative and one false positive report. Reports which will agree 100 per cent with the pathology found will probably never be attained, any more than is the case with cholecystography at the present time.

There are several kinds of cholangiography:

1. Intravenous cholangiography.

This manuscript was prepared for presentation during the St. Petersburg Assembly of The Southeastern Surgical Congress, April 1–4, 1957, St. Petersburg, Florida.

2. Operative cholangiography:
   A. Primary or immediate, when the procedure is done after the abdomen is opened but before the ducts are explored.
   B. Secondary or delayed, when the test is used to check the results of choledochotomy before the abdomen is closed.
3. Postoperative cholangiography, carried out any time after closure of the abdomen by injecting dye through the T tube.

Operative cholangiography requires very little special equipment. An operating table containing a Bucky diaphragm is ideal but satisfactory results are obtained by using a Lisholm grid cassette which may be slipped in and out of a simple wooden frame placed between the pads of the operating table. A portable x-ray unit may be used to obtain perfectly satisfactory films. Everything else needed for the procedure is standard operating room equipment.

Choledochotomy is, of course, not carried out routinely with every cholecystectomy but rather only where certain special conditions indicate the likely presence of stones. There are only three positive indications for choledochotomy. First, the presence of obstructive jaundice or a history of it. One half of the patients who have gallstones and jaundice will be found to have stones in the common duct. This is a sufficiently high percentage to make exploration of the common duct almost mandatory. But it must be remembered that only one half of those patients who do have choledocholithiasis will give any history of jaundice. So that while the history of jaundice makes exploration of the duct mandatory it must be remembered that its absence does not relieve us of the responsibility for applying the other indications for choledochotomy.

The second positive indication for exploration of the common duct is the presence of an enlarged or thickened duct. Unless the duct is tremendously enlarged its size can not be properly evaluated by palpation or inspection until after a certain amount of dissection has been done. It is only after the peritoneum, including its accompanying fatty and vascular tissue has been removed from the anterior surface of the duct that one can actually determine its size and appearance. The normal duct is between 6 and 7.5 mm. in diameter and any duct larger than 8 mm. in diameter should be explored regardless of other signs.

Palpation of a stone or stones in the common duct is the third positive indication for exploration of the duct. It is a very surprising fact that only 5–15 per cent stones in the common duct can be palpated and yet the absence of palpable stones and the absence of jaundice are frequently taken as sufficient evidence that the duct need not be explored. Unless the duct is exposed and its size determined many stones will be left behind without benefit of exploration.

In addition to these three positive indications there are a good many other conditions which, under certain circumstances, or when taken in conjunction with each other, call for an exploration of the duct. It is in the presence of these indications that immediate cholangiography may be of the greatest value in determining whether or not a choledochotomy should be done. These generally accepted relative indications are: (1) history of frequent attacks of biliary colic; (2) history of chills or fever; (3) multiple small stones in the gallbladder, es-

pecially if there is any enlargement at all of either the cystic or the common duct; (4) sediment or abnormal color of the bile aspirated from the duct; (5) x-ray evidence by intravenous cholangiography of stone in the common duct. In additon some surgeons consider the following as indications at least for cholangiography: (1) the noncalculous gallbladder with biliary tract symptoms; (2) the small contracted gallbladder which contains stones; (3) enlargement of the head of the pancreas; (4) history of nausea and vomiting; (5) history of epigastric rather than right upper quadrant pain.

The incision of my choice for cholecystectomy and choledochotomy is the right subcostal. The transverse, the right paramedian or right rectus are used by many with satisfaction. The right thoraco-abdominal will provide maximum exposure but is found necessary only in the rarest of cases. Inspection and palpation of the gallbladder, liver, stomach and duodenum with palpation of the common duct and head of the pancreas are carried out before the packs are placed.

The surgeon had best stand on the left side of the table as he will find that palpation, inspection and instrumentation of the duct is much more satisfactory from this position. Laparotomy packs, properly placed and held by retractors are essential for good exposure.

If it is certain that the gallbladder is to be removed a long Kelly clamp is placed on the fundus of the gallbladder and used for traction to place slight tension on the cystic duct. With Metzenbaum scissors the peritoneum overlying the junction of the gallbladder and the cystic duct is divided and the incision is carried first around the base of the gallbladder all the way to the serosal reflection onto the liver both laterally and mesially, and second, downward over the cystic duct and along the anterior surface of the common duct. The greatest care must be taken with this incision to divide only the peritoneum as injury to either the cystic or right hepatic artery can easily occur. The cystic duct is then completely isolated by sharp and blunt dissection from the gallbladder all of the way to its insertion into the common duct. It must be remembered that the cystic duct often appears to insert into the common duct at a high level when actually it only approximates the common at this point and then runs parallel and adjacent to it for some distance before entering it. Unles the dissection is meticulous and complete in such instances, the choledochotomy incision may inadvertently be made into the cystic instead of into the common duct, with subsequent technical difficulties in carrying out the exploration of the duct.

The peritoneum overlying the suprapancreatic portion of the common duct is then incised and stripped away exposing the anterior surface of the duct for at least half of its circumference. There are usually several veins which have to be divided and these may be ligated either before or after division. The common duct is now aspirated with a small syringe and a no. 22 hypodermic needle. This is done primarily as a precaution against mistakenly opening the hepatic artery or the portal vein, and secondarily it allows observation of the common duct bile.

This much of the operation should be done routinely in every case. It is only after this much exposure that the surgeon can intelligently decide whether

choledochotomy or cholangiography or both or neither should be done. Now keeping in mind the significant portions of the patients history, physical and laboratory findings and by direct inspection and palpation of the gallbladder, cystic and common ducts and by observation of the aspirated common duct bile the indications for further operative procedures which have been previously discussed may be applied. Both choledochotomy and cholangiography have their shortcomings and it is only by a judicious combination of the two procedures that we can get our best results.

If any of the three positive indications for choledochotomy exist—jaundice, palpable stone in the duct or an enlarged duct—then there is little to gain by doing an immediate cholangiogram. A negative cholangiogram at this time would not be sufficiently reliable to outweigh the evidence of positive indications for choledochotomy. A positive cholangiogram showing a certain number of stones in the duct would be of relatively little value when the duct is to be explored anyway. In such instances it will be of more worth to reserve the procedure for evaluating the final results of the exploration. On the other hand if the indications for choledochotomy are less clear cut, an immediate cholangiogram may quickly decide the question. Completely negative pictures made under such circumstances may satisfy the surgeon and thus prevent many unnecessary choledochotomies. But if stones are seen in the film then one knows that the operation will not be complete without a choledochotomy.

To proceed with the cholangiogram a transverse incision is made halfway through the cystic duct at a point about 2 cm. above its junction with the common. After the appropriate sized ureteral catheter or polyethylene tubing has been slipped into the duct, it is held in place by a snug tie around the lower end of the duct. Care must be taken not to push the catheter all of the way into the duodenum. When the x-ray technician has his equipment properly in place and the anesthesiologist is ready to produce apnea, about 10–15 cc. of the dye may be injected fairly rapidly and the first film made immediately. Diodrast 35 per cent is preferable and the amount of dye injected will depend somewhat on the general appearance of the size of the ductal system. A second film made after about 3 minutes may be helpful in showing the free passage of dye into the duodenum. While these films are being developed the cholecystectomy may be completed. With a properly organized team the additional time thus required for the cholangiography should not be more than 10 minutes.

There are certain technical precautions which must be meticulously carried out. Of course before the anesthetic is started the patient must be placed properly over the film holding frame on the table. Before the dye is injected all instruments and laparotomy packs must be removed from the field of operation. For this reason it is better to suture isolation towels to the skin instead of using towel clips. It is essential that air bubbles be kept out of the duct as they are difficult to distinguish on the film from the negative shadow of a stone. This is best done by filling the catheter with dye or saline solution before it is inserted into the duct and then by aspirating a little bile back into the syringe before the injection is made. The anesthesiologist must be prepared to produce apnea upon a signal

from the surgeon and to maintain this apnea for the duration of the film exposure. On a good many occasions I have repeated the injection immediately because of unsatisfactory films and have never seen any adverse effects from the double dose of dye.

If on viewing these films the surgeon does not see any suspicious shadows in the ducts and the dye freely enters the duodenum then he may, with a high degree of safety, believe that choledochotomy is not indicated. The catheter can be removed and the stump of the cystic duct ligated close to the common. If on the other hand suspicious shadows are seen, or the dye does not flow into the duodenum, then a choledochotomy must be carried out.

To do this a longitudinal incision about 2 cm. in length is made in the anterior wall of the supraduodenal portion of the common duct. The duodenal end of the duct can best be palpated if the duodenum is reflected medially. This requires only an incision of the peritoneum lateral to the duodenum and a small amount of blunt dissection with the fingertips. If a stone is palpated it is much better not to use an instrument for its extraction but rather to milk it upward by manipulation between the thumb and forefinger of the left hand. If this can not be done then a scoop or stone grasping forceps may be used, and very occasionally it is necessary to crush a stone with the forceps before delivery. A Bakes dilator makes an ideal instrument to probe the lower end of the duct. Standing on the left of the table and controlling the handle of the dilator with the right hand, the fingers of the left hand beneath the pancreas and the duodenum are able to palpate any remaining stone against the head of the dilator. The exact location of the ampulla of Vater can be determined with the dilator and this is the most likely place for stones to be found. If a 5 mm. dilator passes into the duodenum with ease, one can at least be assured that there is no obstruction to the flow of bile. Whether the dilator is actually in the duodenum may be difficult to determine by palpation but when brought up against the anterior duodenal wall it can be positively identified by its silvery appearance when seen through the bowel wall. After withdrawing the dilator the duct should be thoroughly irrigated with saline solution through a urethral catheter. A similar exploration should be made of the common hepatic duct above the incision, using palpation, scoops, forceps and irrigation.

A very few surgeons close the incision in the common duct without drainage but the majority prefer to use a T tube. The size of the tube must be chosen to fit the duct, preferably not too snugly. Interrupted no. 000 chromic catgut sutures on an atraumatic needle are then used to close the duct firmly around the base of the long limb of the T tube. Considerable information can be gained at this point by pouring saline solution into a large Asepto syringe attached to the end of the T tube. If there is any leak in the closure of the duct saline solution will be seen flowing from it. Such a leak can be controlled easily with another suture or two. If the saline solution does flow readily by gravity in the absence of a leak it must be obvious that the duct and the sphincter are grossly patent. This irrigation should also serve to eliminate air bubbles from the tube and duct.

A secondary cholangiogram may be done at this point by injecting dye through

the T tube. It is far better to discover through cholangiography at this point that a stone remains in the duct than it is to make such a discovery after the abdomen has been closed. It is not too late at this point to remove the T tube and re-explore the duct.

Very occasionally it is necessary to open the duodenum in order to explore the ampulla under direct vision or to remove a stone impacted in this area. Discussion of transduodenal choledochotomy is beyond the scope of this paper.

Finally, postoperative cholangiograms should be used as a double check before removing the T tube.

It has been the practice of the author for the past 5 years to use operative cholangiography routinely first to determine the necessity for choledochotomy in the doubtful cases and second as a check for remaining stones at the end of choledochotomy. It is my conviction that the test when used in this way is of real value in preventing the occurrence of residual common duct stones.

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ACUTE GASTRODUODENAL PERFORATIONS: A STUDY OF THREE HUNDRED AND EIGHTY-ONE PATIENTS

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Acute perforation of the stomach and duodenum continues to be a serious condition with a high mortality rate. Major advances in anesthetic technics, antibiotic therapy, blood transfusions, and an increasing knowledge of metabolic changes along with fluid and electrolyte therapy have measurably decreased the mortality rate. However, the management of the perforation remains a controversal issue. Advocates of nonoperative therapy, simple closure and primary gastrectomy have reported the cases of a series of patients supporting the individual types of therapy. Regardless of the method used, the mortality rate remains high. Management and therapy may only be improved by continued study of gastroduodenal perforations and analysis of large series of patients.

The data utilized here is derived from a study of patients in a charity hospital serving a population of 800,000. The annual admission rate to the General Surgery Service is approximately 4,500. The ratio of Negro admissions to white admissions is 2 to 1. During the 10 year period between Jan. 1, 1947, and Sept. 1, 1956, a total of 381 patients with perforated gastroduodenal lesions were admitted to Grady Memorial Hospital, Atlanta, Georgia. A diagnosis of perforation was made when one or more of the following criteria was encountered: (1) a history consistent with gastroduodenal ulceration and free air by x-ray examination, (2) surgical observation of the perforation, and (3) postmortem examination revealing a perforation.

ANALYSIS

All but 25 of the 381 patients were treated surgically. Thirteen perforations were discovered only at autopsy. Conservative therapy was instituted only when surgery was refused, the patient was moribund, or an error in diagnosis occurred.

The age of the patient varied from 3 days to 89 years. Perforations occurred predominantly in the 30 to 70 year age group with the mortality being high in the young (below 10 years) and in the older age groups (fig. 1). There were 339 males with perforations and 42 females for a ratio of 8:1. There were 228 white and 153 Negro patients, a ratio of 1.5:1. Perforations were slightly more frequent during the Spring than in any other season (fig. 2). Approximately two thirds of the patients developed their initial pain between noon and midnight.

A history of a previously proved ulcer or symptoms strongly suggestive of ulcer was obtained from 74 per cent of the patients. Duration of ulcer symptomatology varied from less than 1 year up to 30 years before perforation. In

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Presented during the St. Petersburg Assembly of The Southeastern Surgical Congress, April 1–4, 1957, as the winning paper in the Scientific Award Contest.

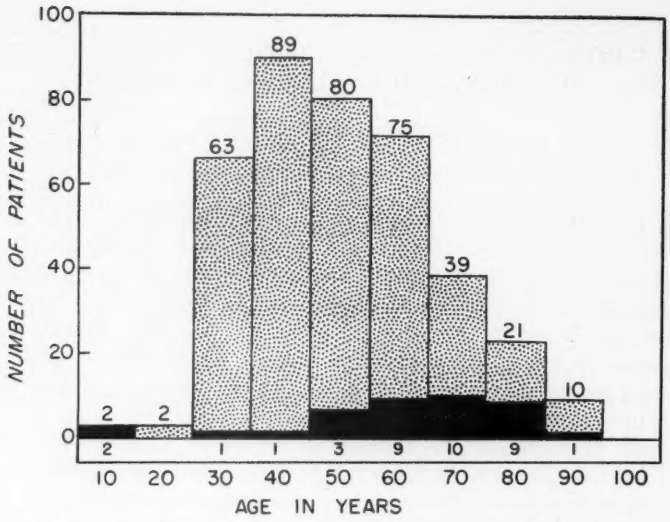

FIG. 1. The number of patients and the mortality encountered in each age group

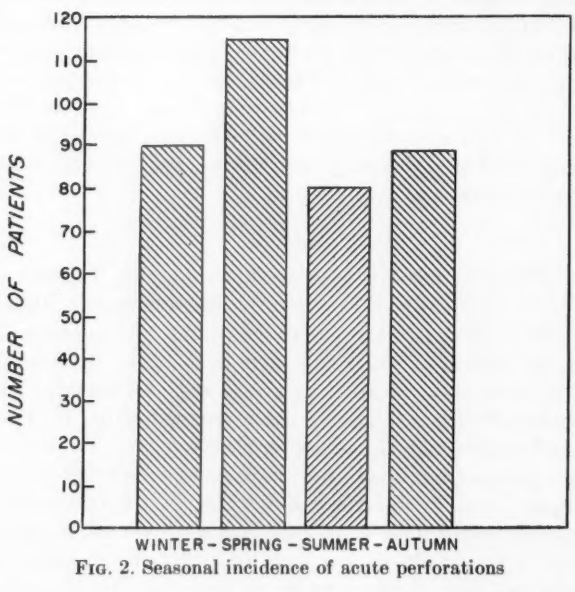

FIG. 2. Seasonal incidence of acute perforations

many patients, symptoms associated with the acute perforation was the first indication of their illness. Thirty patients in this series had a previous perforation and 4 had 2 previous perforations.

The onset of epigastric pain was the most frequent initial symptom of per-

foration (88.5 per cent). Radiating pain to the shoulders occurred in approximately one fourth of these patients. Vomiting was an associated symptom in one half of the patients.

Examination revealed marked abdominal tenderness in 88.5 per cent of the patients. Audible peristalsis was present in approximately one-fourth of the patients. Bleeding as evidenced by melena was present in 8.6 per cent. The pulse rate was elevated above 100 per minute in over one half of the patients and the temperature was elevated above 99 F. in three-fourths of the patients.

Laboratory examinations revealed white blood cell counts ranging from 5000 per cu. mm. to 40,000 per cu. mm. The white blood cell count was elevated above 10,000 cu. mm. in three-fourths of the patients. Hemoconcentration was evident in approximately one half of the patients with values ranging between 15 and 25 grams per cent hemoglobin. Anemia was marked in 5 per cent of the series. Free peritoneal air was demonstrated in 74.5 per cent of the patients x-rayed.

An admission diagnosis of perforated ulcer was made in 331 cases. A preoperative diagnosis of acute appendicitis was made in 16 cases. Other admission diagnoses are varied (table 1). Only 3 of the nonoperative deaths were diagnosed as perforated ulcer (table 2).

Treatment was instituted as soon as the diagnosis of perforation was made. Intravenous fluid therapy, whole blood transfusions as required, and nasogastric suction were begun before surgery. Of the 25 patients treated nonoperatively, only 12 had therapy directed toward the perforation. Perforations occurred in 4 patients hospitalized for other reasons. As observed by other authors, this in

TABLE 1

Admission diagnosis

Diagnosis	Number
Perforated ulcer	329
Acute appendicitis	16
Gastrointestinal bleeding	5
Pneumonia	4
Intestinal obstruction	4
Mesenteric thrombosis	3
Acute cholecystitis	3
Gastrointestinal malignancy	2
Marginal ulcer perforation	3
Uremia	2
Pancreatitis	2
Acute abdomen	2
Pelvic inflammatory disease	1
Dissecting aneurysm	1
Incarcerated hernia	1
Cerebrovascular accident	1
Lower nephron nephrosis	1
Myocardial infarction	1
Total	381

TABLE 2

Nonoperative deaths

No.	Age in Years	Sex	Admission Diagnosis	Site of Perforation	Complicating Conditions	Cause of Death
1	56	M	Perf. ulcer (38 hrs.)	?	Shock	Refractory shock,* peritonitis
2	27	M	Perf. ulcer (36 hrs.)	?		Undetermined, died on 15th. hosp. day*
3	67	M	Mesenteric thrombosis (12 hrs.)	Duodenal		Perforated ulcer, peritonitis
4	54	F	Perf. ulcer (24 hrs.)	?	Shock	Refractory shock*
5	67	F	Myocardial infarction (72 hrs.)	Duodenal	Shock	Perforated ulcer, peritonitis
6	50	F	Cerebrovasc. accident (?)	Duodenal	Coma	Perforated ulcer, peritonitis
7	48	F	Pneumonia (?)	Duodenal	Shock, alcoholism	Perforated ulcer, peritonitis
8	50	F	Mesenteric thrombosis (24 hrs.)	Duodenal	Shock	Perforated ulcer, peritonitis
9	74	M	Gastrointest. bleeding (12 hrs.)	Duodenal	Shock	Perforated ulcer, peritonitis
10	39	F	Malignant hypertension (?)	Gastric	Shock, uremia	Perforated ulcer, peritonitis
11	54	M	Rheumatic heart disease (8 days)	Duodenal	Congestive failure, uremia	Perforated ulcer, peritonitis
12	63	M	Myocardial infarction (1 day)	Gastric	Cancer of prostate	Perforated ulcer, peritonitis
13	72	M	Pneumonia (21 days)	Duodenal	Prostatitis, septicemia	Perforated ulcer, peritonitis
14	41	F	Lower nephron nephrosis (1 day)	Duodenal	Transfusion reaction	Perforated ulcer, peritonitis
15	67	F	Pneumonia (14 days)	Duodenal	Shock	Perforated ulcer, peritonitis
16	80	M	Pneumonia (10 days)	Duodenal		Perforated ulcer, peritonitis

The duration of symptoms prior to admission to the hospital is shown in parenthesis beneath the admission diagnosis.

* No autopsy performed.

itself is associated with a high mortality (4 died) because of delayed examination and recognition after the initial complaint of abdominal pain.

Three hundred and fifty-six patients were submitted to surgical therapy within a few hours following admission. Surgery was postponed in others, of necessity,

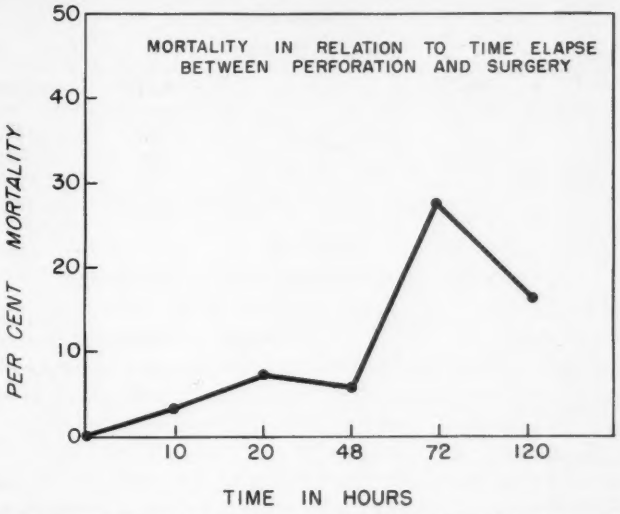

FIG. 3. The percent mortality in relation to the time elapse between perforation and surgery.

to treat shock and dehydration. The time lapse between onset of symptoms of perforation and surgery is closely correlated with the mortality rate. The per cent mortality in relation to delay in surgical closure is shown in fig. 3.

Simple closure of the perforation was performed in 340 patients. Two hundred and twenty-two were closed with a Lembert suture and an omental graft, 101 were closed with a small tag of omentum being sutured loosely over the perforation, and 17 were closed with a Lembert type suture alone. Four perforations at surgery were sealed to the degree of requiring no further closure. A primary subtotal gastrectomy was performed in 12 patients.

Duodenal perforations were the most frequent of the perforations encountered. Two hundred and sixty-six patients had perforations in the first portion of the duodenum on the anterior surface. Five perforations were located in the first portion of the duodenum on the posterior surface. One perforation was located in the second portion of the duodenum and one in the third portion of the duodenum. Eighty perforations in the antrum and prepyloric region of the stomach were encountered. There were 3 marginal ulcer perforations. In addition to those found at surgery, 11 duodenal and 2 gastric perforations were demonstrated at autopsy. The mortality in relation to the site of perforation is shown in table 3.

One hundred biopsies, including 12 specimens taken at primary gastrectomy, of acute perforations were taken at exploration. Ninety-five were reported as benign; however, one proved to be a false negative with one patient returning with malignant obstruction. Two were suspicious of malignancy, but proved to be negative on subsequent resection. Three were positive for malignancy, one being a lymphosarcoma.

TABLE 3

Site of perforations

Site	Number	Mortality Rate
Gastric	82	13.4%
Duodenal	284	7.4%
Marginal	3	33.3%

TABLE 4

Postoperative complications encountered in 90 patients

Complication	Number
Wound infection	33
Atelectasis	12
Electrolyte imbalance	13
Pelvic abscess	11
Subphrenic abscess	9
Ileus (severe)	8
Wound dehiscence	7
Wound hematoma	6
Acidosis (diabetic)	3
Pneumonia	3
Thrombophlebitis	2
Postoperative obstruction	2
Postoperative hemorrhage (ulcer)	2
Congestive heart failure	2
Lower nephron nephrosis	1
Ascites (etiology unknown)	1
Pulmonary infarction	1
Myocardial infarction	1
Cerebrovascular accident	1
Delerium tremors	1
Septicemia	1
Total	120

Postoperatively patients were maintained on nasogastric suction, parenteral fluids, and either chemotherapy or antibiotic therapy. Duration of nasogastric suction varied from 1 to 9 days. Two hundred and forty of the surviving patients were on a solid diet by the fourth postoperative day.

Complications were encountered in 90 patients of the surgically treated group. Many of these had combined complications. Wound infection, pulmonary complications, and electrolyte imbalance were the most frequent (table 4).

Twenty patients died in the immediate postoperative period, a mortality of 5.6 per cent (table 5). Cardiac difficulties and refractory shock were involved in approximately 50 per cent of the deaths following simple closure. As pointed out previously, a prolonged delay between onset of symptoms of perforation and surgical closure is also related to the high mortality rate. Information relative to

TABLE 5

Management of perforations

Method	Number	Mortality Rate
Operative	356	5.6%
Simple closure	344	5.8%
Primary gastrectomy	12	0
Nonoperative	25	64.0%
Total	381	9.4%

the location of the ulcer, elapse of time between perforation and closure, and complications is summarized in table 6.

Sixteen patients treated by conservative measures died during their initial hospitalization, a mortality of 64 per cent. Again, refractory shock appeared to be the main complication leading to a fatal outcome. A diagnosis of perforation was made in 12 of the 25 patients. This diagnosis was made on the basis of physical findings, a history of ulcer symptoms, and the presence of free peritoneal air by x-ray examination in 7 of the surviving patients. A diagnosis of perforation was made in an eighth patient who had an ulcer demonstrated by gastrointestinal series 6 months prior to admission, but no free air by x-ray on admission. The ninth patient treated conservatively had a history strongly suggestive of perforation and had had two previous perforations. Of the surviving group 6 had refused surgical intervention, and conservative therapy was elected as the therapy of choice in the remaining 3. Table 7 gives information relating to this group of patients.

Three hundred and forty-five patients, 336 treated surgically and 9 nonoperatively, were discharged from the hospital with plans for follow-up in the out-patient clinics. One hundred and ninety-six (58.3 per cent) of the surgically treated group returned for follow-up ranging from 1 to 10 years. Six patients required gastrectomy subsequent to simple closure of gastric perforations. Thirty-six patients required gastrectomy subsequent to simple closure of duodenal perforations. Both survivors of marginal ulcer perforation required re-section (table 8). Obstruction was the most frequent indication for secondary gastrectomy in patients having had duodenal perforations. Massive hemorrhage was the indication for two thirds of the secondary procedures in patients having had gastric perforations (table 9). A continued follow-up of this group requiring a secondary gastrectomy revealed 40 patients to be asymptomatic and pleased with the results of their surgery. One patient died of malignancy. Two patients developed marginal ulcers. One who had a Billroth I gastric resection required re-resection and the other responded to conservative measures. One patient has continued to have symptoms of mild dumping.

The remaining 152 patients are being followed in a Gastrointestinal clinic. Approximately 40 per cent of this group continue to have infrequent ulcer symptoms. Repeat gastrointestinal x-ray studies have revealed persistent duodenal deformities in many of these patients.

TABLE 6

Surgical deaths

No.	Age	Sex	Type of Ulcer	Elapsed Time Perforation to Surgery	Complication	Cause of Death
1	3 wks	M	Duod.	Undetermined	Diarrhea, dehydration	Dural venous sinus thrombosis
2	70	M	Gast.	12 hours	Myocardial infarction	Pulmonary embolus
3	73	M	Gast.	5 hours	Hypotension	Open posterior gastric perforation
4	55	M	Duod.	11 hours	Hypotension	Cardiac failure, peritonitis
5	76	M	Gast.	22 hours	Hypotension	Electrolyte imbalance peritonitis
6	81	M	Gast.	15 hours	Myocardial infarction	Myocardial infarction
7	66	M	Gast.	9 hours	Hypotension	Refractory shock (No autopsy)
8	63	M	Duod.	4 hours	Congestive failure	Bronchopneumonia, uremia
9	54	M	Duod.	3 hours	Diabetic, insulin shock	Myocardial infarction (No autopsy)
10	48	M	Gast.	72 hours	Electrolyte imbalance	Peritonitis (No autopsy)
11	49	M	Gast.	48 hours	Hypotension	Refractory shock (No autopsy)
12	65	F	Duod.	48 hours	Diabetes	Peritonitis, uremia
13	75	M	Duod.	13 hours	Congestive failure	Pulmonary embolus
14	69	F	Gast.	120 hours+	Hypotension	Refractory shock (No autopsy)
15	54	M	Marg.	5 hours		Myocardial infarction
16	67	M	Duod.	31 hours		Refractory shock (no autopsy)
17	65	M	Duod.	17 hours	Cardiac	Myocardial infarction
18	72	M	Duod.	34 hours	Carcinomatosis	Refractory shock
19	67	M	Duod.	11 hours	Lower nephron nephrosis	Electrolyte imbalance (no autopsy)
20	3 days	M	Duod.	20 hours		Refractory shock (no autopsy)

Of the surviving group treated conservatively, 8 returned for follow-up. Three of this number have remained asymptomatic without diet or medication for a 3 to 4 year period. Two of this group required emergency gastrectomy for massive hemorrhage within 12 months following discharge. One patient had a gastrectomy for pyloric obstruction 6 months following what was thought to be his third perforation. Another patient in this group refused surgery although x-rays revealed a lesion in the stomach suggestive of malignancy. This patient died within 1 year following discharge from the hospital.

TABLE 7

Survivors of nonoperative therapy

No.	Age in Years	Sex	Elapsed Time Onset Symptoms to Admission	Duration of Ulcer Symptoms	Reason for Nonoperative Therapy	Comment
1	67	M	48 hours	25 years	Considered as poor surgical risk	Returned in 6 months. Emerg. gastrectomy for bleeding
2	82	M	14 days	14 days	Considered as poor surgical risk	X-ray revealed lesion of stomach. Surgery refused. Died in 1 year
3*	55	M	2 days	7 months	Refused surgery	X-ray revealed ulcer. No follow-up
4	55	M	12 hours	1 month	Refused surgery	Asymptomatic, 4 year follow-up
5	29	M	12 hours	none	Refused surgery	Persistent ulcer symptoms. 2 year follow-up
6	32	M	72 hours	6 years	Postperforation 72 hours. Not acceptable risk	Asymptomatic 3 year follow-up
7	34	M	12 hours	4 days	Refused surgery	Asymptomatic 4 year follow-up
8	49	M	12 hours	6 years	Refused surgery	Gastrectomy for bleeding 1 year after discharge
9†	36	M	8 hours	7 years	Refused surgery	Gastrectomy for obstruction in 6 months

* No free air demonstrated by x-ray examination.

† No free air demonstrated. Patient had had a previous perforation.

TABLE 8

Follow-up of all surviving patients having simple closure of perforations

Site of Perforation	Surviving Simple Closure	Secondary Gastrectomy	Percentage
Gastric	69	6*	8.7%
Duodenal	247	36†	14.6%
Marginal	2	2	100.0%
Total	318	44	13.8%

* 3 required gastrectomy within 12 months. 5 (83%) required gastrectomy within 24 months.

† 21 required gastrectomy within 12 months. 31 required gastrectomy within 24 months (86%).

TABLE 9

Indications for secondary gastrectomy

Indication	Gastric	Duodenal	Marginal	Total
Obstruction	1	20	0	21
Subsequent perforation	0	6	1	7
Intractable pain	0	3	0	3
Hemorrhage	4	7	1	12
Malignancy	1	0	0	1
Total	6	36	2	44

DISCUSSION

Reduction in the mortality of acute gastroduodenal perforations in the past 40 years has been accomplished by earlier diagnosis, improved anesthesia, whole blood transfusions, parenteral fluid and electrolyte therapy, and antibiotics.[10, 17, 4, 8] In recent years, attention has been diverted specifically to the management of the perforation. A survey of large series of patients 1 to 10 years after having had simple closure of perforations has revealed ulcer symptoms in approximately 20 per cent and subsequent surgery in 49 per cent.[9] Other studies have reported similar findings.[16] This high incidence of persistent difficulty has led many to advocate primary gastrectomy as definitive therapy for the acute perforation.[1, 2, 5, 6, 9] In contrast, there are other authors who advocate nonoperative therapy.[12, 13, 14, 15] Many still prefer simple closure of the acute perforation with primary gastrectomy being reserved for patients with specific indications.[3, 7] The advantages and disadvantages have been extensively discussed in the literature.

While many of the findings in this study closely parallel those reported by other authors, several conclusions may be made or restated. Early diagnosis and institution of therapy are paramount in reducing the mortality. Elderly patients and patients with cardiac disease will require vigorous preoperative and postoperative therapy. Cardiac difficulties and refractory shock were responsible for 50 per cent of the deaths in both the surgically and conservatively treated patients in this study.

From our poor results with nonoperative measures in 12 patients diagnosed as having a perforation, we cannot advocate this plan of therapy. Admittedly, this group of patients were poor surgical risks initially. While the results with primary gastrectomy have been good, we cannot fully evaluate this method of therapy because of the small number in this series and the short follow-up since surgery (1 to 2 years). However, with the selection of patients, primary gastrectomy may well be the therapy of choice.

The present indications for primary gastrectomy for acute gastroduodenal perforations at this hospital are as follows: (1) previous perforation, (2) associated or previous gastroduodenal hemorrhage, (3) gastric perforations, and (4)

intractability on ulcer regimen prior to perforation. The following criteria must be present in association with the specific indication: (1) the general condition of the patient is good, (2) the local abdominal condition will allow resection, (3) the perforation is not over 12 hours old, and (4) the patient is not over 65 years of age. Many patients have an indication for primary gastrectomy, but are poor surgical risks. Here simple closure is advocated, followed by secondary gastrectomy as suggested by other authors.[11]

Continued postoperative follow-up of patients surviving gastroduodenal perforations may necessitate a re-evaluation and change in the specific types of therapy. A planned follow-up over a long range period is being established at this hospital and should provide information for a future report.

SUMMARY

Three hundred and eighty-one patients with gastroduodenal perforations at Grady Memorial Hospital during a 10 year period between 1947 and 1956 have been reviewed.

The mortality is closely related to time lapse between onset of perforation and institution of therapy, age of the patient, location of the perforation (gastric perforation having the higher mortality), and concomitant disorders.

Simple closure of the perforation or in selected patients with specific indications primary gastrectomy is the treatment of choice.

Secondary gastrectomy within 8 to 10 weeks is indicated in patients who are initially poor surgical risks but have an indication for gastrectomy.

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EDITORIAL

SOME CURRENT CONCEPTS IN TREATMENT OF BURNS

During the past few years, much progress has been made in the knowledge and understanding of many problems involved in thermal burns. During all wars and disasters, large numbers of burns are seen. This crystallizes current thinking; but, apparently, these lessons must be relearned ever so often. Since World War II, investigation in the disturbed physiology and treatment of burns has made rapid strides. With the additional threat of atomic war and high speed transportation, the magnitude of the problem has been greatly increased.

There are three basic groups of burns: those of a minor degree; those which are moderate to severe; and the critical ones, in which, usually, no form of therapy is successful. It is necessary to evaluate each in order not only to render proper treatment but, also, to prevent useless effort in event of a major catastrophe. It is difficult to be certain of the second group; since many in this category are, frequently, not recognized and so fail to receive adequate therapy before irreparable damages have occurred. These offer the greatest challenges for reduction in mortality and morbidity, since many are considered borderline but later become critical.

The fundamental changes in a burn should be well appreciated in order that care may be uniformly rendered. Facilities should be made available in any location; but it should be emphasized that, unless the personnel are able and willing to expend a large amount of time and effort, the best results cannot be expected. It is easy to be enthusiastic in the treatment of burns at first, only to lose this enthusiasm during the succeeding days. The late complications may be equally critical in the survivors in spite of an excellent immediate response to the injury. The mortality has not been materially reduced, but the morbidity has been lessened, by the utilization of the established principles.

In the event of mass casualties, it is necessary that all professional aid be available. Trained lay personnel, as well as nurses and dentists, may be the ones to render total care under such circumstances. Even then, many may go unattended for lack of available trained assistance. This threat offers a need for preparation and education through our civil defense and other organizations.

The use of ACTH and cortisone was suggested as possible means of lessening systemic effects and decreasing local manifestations, but this has been since proved to be of limited or doubtful value. Studies have shown that in some instances nutrition could be improved, but the harmful effects from continued use of these materials may sometimes offset any benefit that might be derived.

There is much to be desired from systemic and local use of antibiotics. Infections in burns continues to be a great problem. In second and third degree burns, there is, eventually, considerable infection; and many patients develop septicemia. Blood cultures and sensitivity studies will substantiate such an opinion and aid effectively in utilizing the suitable antibiotics. It is well to hold in reserve perhaps one or, maybe, two of the broad spectrum antibiotics for the

time when the septicemia develops and, also, during the period before and after grafting. As yet, no appreciable benefits can be found in the continued use of local antibiotics on burns.

Enzymatic debridement in some instances will hasten preparation of a burn for grafting. This, however, has a limited value due to the expense; therefore, it is believed that its routine use is contraindicated. The most satisfactory debridement is that of surgical excision after demarcation has been established. Recent experiments have been made by several investigators to determine the viability of skin. These, mainly, are based on staining characteristics of the destroyed cells. This permits an early differentiation which would, perhaps, allow for excision and grafting. At the present time, this is in the experimental stage; and dependence on clinical judgment must be used.

In view of great shortage of skin in extensive third degree burns, many investigators have made efforts of early replacement by dressing with homologous grafts utilizing banked skin and other substitutes. These efforts have been, under certain conditions, rewarding; and perhaps they should be persued on a broader scale. Recent attempts have been made to utilize very fine particles of skin by dividing it in a blender and applying these small fragments to the granulating surface in order to cover a larger area.

Active interest must be maintained in newer developments and easier methods of treatment of burns if a large number are to be successfully treated.

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BOOK REVIEWS

The Editors of THE AMERICAN SURGEON *will at all times welcome new books in the field of surgery and will acknowledge their receipt in these pages. The Editors do not, however, agree to review all books that have been submitted without solicitation.*

Training of the Lower Extremity Amputee. By DONALD KERR, B.B.A., AND SIGNE BRUNNSTROM, M.A., Springfield, Illinois, Charles C Thomas, Publisher.

This must have been a most difficult book to write as there are so many variables involved,—the patient and his residual assets and liabilities, the stump, the prosthesis, and the rehabilitation goal. While most aspects of the subject are covered, the book is clearly oriented primarily for the young vigorous amputee. Almost 15 per cent of the book is devoted to social dancing and sports, while only brief reference is made to the care of the remaining leg.

There is a tendency to repetition at times. There are occasional statements which might be questioned, such as "An elastic sock is not as effective as proper bandaging, but it is to be preferred to poor bandaging." Actually the elastic shrinker had received wide acceptance and is considered far superior to bandaging by many. The stick drawings are well done for the most part and are quite effective. Some, however, are accompanied by insufficient explanatory data.

On the whole the authors have handled a most difficult subject rather well. This book would appear to be of value to the young vigorous lower extremity amputee and to therapists who work with such patients.

SAMUEL M. REICHEL, M.D.

BOOKS RECEIVED

Books received are acknowledged in this section, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

Diseases and Disorders of the Colon. By ANTHONY BASSLER, M.D., F.A.C.P., F.A.C.G., LL.D., Charles C Thomas, Publisher, Springfield, Illinois.

The Use of Muscle Relaxants in Anesthesiology. By FRANCIS F. FOLDES, M.D., Charles C Thomas, Publisher, Springfield, Illinois.

Clinical Management of Varicose Veins, 2nd Ed. By DAVID W. BARROW, M.D., PAUL B. Hoeber, Publisher, New York City.

Stress and Strain in Bones. By F. GAYNOR EVANS, Ph.D., Charles C Thomas, Publisher, Springfield, Illinois.

Practical Office Gynecology. By ALBERT DECKER, M.D., AND WAYNE H. DECKER, M.D., F. A. Davis Company, Publisher, Philadelphia.

Liver, Biliary Tract and Pancreas. By FRANK H. NETTER, M.D., Ciba Pharmaceutical Products Company, Publisher, Summitt, New Jersey.

TRACHEOTOMY: A CLINICAL AND EXPERIMENTAL STUDY

PART II*

THOMAS G. NELSON, MAJOR, M.C., U.S. ARMY

CHAPTER III. CLINICAL MATERIAL (CONTINUED)

Clinical Cases with Secretional Ventilatory Obstruction

There were 162 tracheotomies performed in the patient group with secretional ventilatory obstruction (table 1).

The use of tracheotomy for secretional blockage in association with burns and spinal cord injury has already been discussed. The remaining cases include 118 tracheotomies in association with cerebral diseases and injuries and 29 tracheotomies performed following thoracic injuries and operations.

Cerebral diseases (62 cases). In this group there were 35 operations for bulbar poliomyelitis, seven operations for encephalitis, and 20 operations for other cerebral diseases such as embolism, vascular accidents, barbiturate poisoning, tetanus, and certain medical diseases with associated coma.

The over-all treatment of these diseases has two major facets: (1) corrective and supportive measures directed toward the primary disease, and (2) measures directed toward the prevention and treatment of airway obstruction from retained secretions. Only within recent years has the latter problem been given deserved attention, mainly because secretional obstruction was not recognized earlier as an important factor in the high mortality of these diseases. This failure of recognition resulted from the common tendency to attribute irrational states and alterations of the cardiorespiratory physiology solely to diseased nerve centers.[130] Galloway,[99, 101] and others,[31, 34, 69, 220, 244, 260, 275] have clearly shown that these manifestations are often the result of inadequate respiratory exchange. The results with tracheotomy in this group of seriously ill patients bear out these assertions. The prompt improvement that occurred after tracheotomy in certain patients leaves no doubt that most of the grave effects were due to hypoxia. In many of these patients, every conceivable treatment for secretional obstruction, short of tracheotomy had been tried. Evidence points to the fact that occasionally tracheotomy was too long delayed while postural drainage, pharyngeal and intratracheal aspiration, and other such measures were tried.

The fatality rate in this group of 62 patients was 60 per cent. At lease one-half of the surviving patients was believed to have been saved by the use of tracheotomy. Although materially benefited by tracheotomy, it is conceivable that the other one-half of survivors might have lived without the operation. It was estimated that about 10 per cent of the patients would have fared better if earlier tracheotomy and more diligent aftercare had been employed. The autopsy

* *Editor's note:* This is the second installment of Dr. Nelson's comprehensive review which because of its length, is being printed in three consecutive issues of The American Surgeon. Part I was presented in the July, 1957, edition, and Part III will appear in September.

findings in these few patients revealed a rather distressing frequency of bronchi plugged with mucus and crusts.

Bulbar poliomyelitis (35 cases):—Bulbar poliomyelitis may involve the cranial nerve nuclei, the respiratory and circulatory centers, the cerebrum and the spinal cord.[34, 202] With such widespread involvement, many vital regulatory mechanisms are upset. These disturbances lead to interference with several important bodily functions; namely, swallowing, breathing and coughing, circulation, and cerebral function.[202] Respiratory obstruction may result from laryngeal spasm and vocal cord paralysis, inability to swallow or cough properly, respiratory weakness from paralysis of the diaphragm, and respiratory depression from involvement of the medullary center.

Before 1948, the year the first tracheotomy was performed in one of these 35 cases, the problems of respiratory embarrassment and accumulated secretions were dealt with by postural drainage, as suggested by Durand[79] in 1929, mechanical aspiration of pharyngeal and oral secretions, and aspiration of the tracheobronchial tree by the bronchoscope or by the passage of an intratracheal catheter. Oxygen was given by nasal catheter or mask, and parenteral feedings were used to avoid an influx of fluid into the trachea. When paralysis of the diaphragm or intercostal muscles was present, the respirator was used. If death occurred despite these measures, it was ascribed to progressive involvement of the regulatory centers in the brain stem.

Tracheotomy at first was employed, with caution and rather rigid indications, in a small group of patients with severe bulbar involvement and near death from respiratory embarrassment. The reversal of these serious manifestations in a few patients who otherwise would have died led to a complete reappraisal of the criteria for adequate treatment and a more widespread use of tracheotomy.

The indications for tracheotomy in bulbar poliomyelitis are:[3, 103, 217, 255] (1) Fluid accumulation in the airway with increasing signs of asphyxia. (2) Respirator patients with any evidence of retained secretions. (3) Irrational states not responding to treatment. (4) Progressive bulbar symptoms or signs of vasomotor failure. (5) Spasm or paralysis of the vocal cords.

Several important conclusions were reached regarding the use of tracheotomy in bulbar poliomyelitis:

1. Early or "prophylactic" tracheotomy is advocated. There was an increasing tendency to perform early tracheotomy in these patients as its benefits became better appreciated.

2. Tracheotomy is advised for patients with severe bulbar signs, if a long siege in the respirator is anticipated or if there is clinical or radiologic evidence of retained pulmonary secretions or atelectasis.[69, 255] In fact, tracheotomy should be used in nearly all respirator patients since the respirator may pull secretions into the larynx unless there is a bypass or vent present,[106] or it may cause pulmonary edema if there is respiratory obstruction.[34] Postmortem examination of respirator patients treated without tracheotomy revealed severe atelectasis in over two-thirds of the cases.

3. If tracheotomy is undertaken in a respirator patient who requires con-

tinuous artificial respiration, then maintenance of the airway and respiratory exchange during the time the patient is out of the respirator is best accomplished by using an endotracheal tube coupled to the standard anesthesia machine. The chest respirator, used under these conditions, provided inadequate respiratory exchange and interfered with the performance of the tracheotomy. The use of a face mask and positive pressure was found also to have certain deficiencies. Pharyngeal secretions were easily pushed into the larynx, and oxygen readily passed into the stomach, producing gastric dilatation. Tracheotomy on one or two occasions using these latter devices was a hurried and rather harrowing experience.

4. The tracheotomy opening should be as high as possible, preferably at the level of the second or third tracheal rings, to facilitate aftercare in respirator patients. Difficulties were encountered in the management of two patients with low tracheotomies because it was almost impossible to keep the respirator cuff clear of the tracheotomy opening. In one of these patients low tracheotomy was performed "because of a large thyroid isthmus." Numerous episodes of respiratory distress occurred from the ill-functioning tracheotomy and contributed no small amount to the patient's eventual demise. Various bars, pipes, and surgical retractors have been devised[103, 189, 31, 255] to hold the respirator cuff below the tracheotomy opening. None of these devices can function efficiently if the tracheotomy tube is at the level of the suprasternal notch.

5. The larger sizes of tracheotomy tubes were found to be much more efficient. Easier and more effective aspiration was possible. A better airway was provided and it was easier to adapt the cannula to positive pressure devices, and inhalators,[161] and to the anesthesia machine. In all cases the bypass around the cannula was adequate and no complications as a result of the use of the larger sizes were noted.

6. Vital capacity determinations may be of value in determining the need for respiratory assistance, the need for tracheotomy, and the optimum time to discontinue the use of the tracheotomy. In the acute phase of the disease, if the vital capacity becomes reduced to 60 per cent of normal, then respiratory assistance is generally needed.[209] If a further drop of vital capacity to 25 per cent of normal occurs, tracheotomy is often needed.[198] Plum and Wolff[212] found that the convalescent poliomyelitis patient was able to tolerate a much greater reduction of vital capacity than the patient in the acute phase of the disease, although his respiratory reserve was minimal. When the vital capacity reaches 50 to 60 per cent of normal then the tracheotomy may be discontinued.

7. There should be no great rush to discontinue the use of the tracheotomy until it is certain that the patient can clear his secretions voluntarily and is free of the danger of aspiration. Patients in the convalescent phase of poliomyelitis, although out of the respirator, may still have a limited respiratory reserve, a weak cough, and residuals of pharyngeal paralysis. Sudden obstruction from laryngospasm, from secretions, or from aspirated vomitus is a continuing grave danger facing these patients with marginal ability to ventilate.[198] In addition, any respiratory infection, even a common cold should be viewed with concern.

In two patients a second tracheotomy was required several weeks after discontinuance of the original tracheotomy because of the development of an upper respiratory infection. One of these patients was brought back to the hospital cyanotic and unresponsive. The tracheotomy was reopened quickly, but the patient died shortly thereafter. Postmortem examination revealed that almost the entire tracheobronchial tree was filled with thick purulent secretions. The other patient developed respiratory obstruction due to aspiration of vomitus. Fortunately, the tracheotomy wound was reopened quickly and the airway cleared.

There were 20 deaths in these 35 patients for a case fatality rate of 57 per cent. This represents an improvement over a rate of 75 per cent before tracheotomy was used and compares favorably with the mortality reported by others.[67, 217, 186] These deaths include several patients who barely survived to be placed in a respirator and undergo tracheotomy. There were no deaths directly attributable to complications of tracheotomy, although errors of judgment in the prompt performance of the operation contributed to the death of two patients. The improper use of artificial respiration during tracheotomy temporarily jeopardized the airway in two patients and in two patients the respirator cuff interfered with the airway due to a low tracheotomy (figure 7). Many of the difficulties from interference with the tracheotomy opening by the respirator cuff are avoided with the use of a newer type respirator with a slanting front (see figure 17).

Other cerebral diseases (27 cases):—This group of cases includes seven operations for encephalitis, seven operations for miscellaneous medical conditions with associated coma, and 13 operations for cerebrovascular accidents, cerebral embolism, tetanus, and barbiturate poisoning.

The fundamental problem in the management of respiratory complications associated with these diseases is similar to that of poliomyelitis. However, secretional obstruction was more often related to increased secretions, such as pulmonary edema, and to loss of the cough reflex from coma, rather than to any intrinsic lesion of the neuromuscular pathways for coordinated coughing and swallowing or respiratory weakness.

There were seven patients with encephalitis in whom tracheotomy was performed because of secretional obstruction. Retained secretions resulted mainly from dysfunction of the cough reflex because of coma and cranial nerve lesions. There were two deaths in this group, both due to the primary disease. In three of the five survivors, tracheotomy was believed to be lifesaving. The only complication of tracheotomy was bleeding from the operative wound in one case.

The benefits of tracheotomy in cases of coma from any cause have recently become recognized.[124, 138, 156, 236] Seven of the 27 patients with cerebral diseases had coma in association with diseases such as renal shutdown, septicemia, cirrhosis, diabetes, and porphyria. Although all these patients died, only one was found at autopsy to have any evidence of atelectasis from obstructed bronchi.

In addition to loss of the cough reflex and retained secretions from coma, three of the seven patients had severe pulmonary edema. As noted by Baronofsky,[12] the administration of positive pressure oxygen through the tracheotomy

opening was found to be an efficient method of diminishing the excessive pulmonary secretions. The only disadvantage of this treatment was the extreme drying effect of the oxygen on the tracheal mucosa, which predisposed to inspissation and encrustation of the tracheobronchial mucus. Despite vigorous treatment with saline irrigations, aerosol trypsin, and detergents (Alevaire),[60] postmortem examination in one patient revealed interspersed areas of segmental atelectasis and obstructive emphysema from blockage of the smaller bronchi.[84, 144]

Two of the four patients with cerebrovascular accidents were believed to have survived because of tracheotomy. One of these patients had tracheotomy performed although it was the general feeling that retained secretions were not a problem and the patient was believed to be in a terminal state. A large quantity of thick mucus was obtained after tracheotomy and the patient immediately became responsive and partially oriented. He later recovered fully except for residual paresis and is known to be alive and following a gainful occupation three years after his illness.

One patient with cerebral air embolism that followed the administration of therapeutic pneumoperitoneum was definitely kept alive because of the value of tracheotomy in keeping the airway clear. Full recovery took place in one month. None of the three patients with fatal fat embolism was materially benefited by tracheotomy. Cerebral manifestations were quite severe and pulmonary secretions were a problem, despite almost continuous aspiration through the tracheotomy.

There were three cases of barbiturate poisoning, with one survival. Treatment of severe barbiturate poisoning should include judicious use of oxygen and analeptics, early tracheotomy, if adequate control of secretions is not obtained,[175] and the respirator where necessary for artificial respiration. One death in these three patients was attributed to errors in judgment concerning the use of tracheotomy. The patient, a three-year-old child, had complete respiratory arrest on admission to the hospital ward. Respirations were restarted with the use of an automatic positive pressure device, the pneophore (figure 10), and an endotracheal tube. After several hours spontaneous respirations resumed. The endotracheal tube was left in as an airway, but after several more hours the patient dislodged the tube and developed respiratory obstruction due to edema at the glottis. The endotracheal tube was replaced and emergency tracheotomy was begun. Unfortunately, the endotracheal tube was passed into the esophagus and the surgeon, using the tube as guide, mistakenly entered the esophagus (figure 7). At this point cardiac arrest occurred and the patient later died, despite restoration of cardiac action by massage. This case indicates the unreliability and possible dangers of an endotracheal tube when improperly used for prolonged periods as an airway. It also points out the necessity for identifying the trachea by palpation even during an emergency operation.

Since Spaeth[250] first mentioned that tracheotomy should be used in cases of tetanus, several authors[62, 129, 237, 271] have demonstrated the value of the operation in lowering the mortality of this disease. In addition to treatment with antitoxin, sedatives, oxygen, antibiotics, and curariform drugs, tracheotomy is recom-

mended as a routine procedure in these cases, whether or not respiratory obstruction is present.[62, 237] Turner and Galloway[271] have pointed out that the tetanus patient who is heavily sedated and has respiratory depression from curare presents the same problem in ventilation as does the patient with poliomyelitis. They advocate tracheotomy and the respirator, if necessary. Tracheotomy in tetanus has a dual purpose: (1) to bypass mechanical obstruction from pharyngeal and laryngeal spasm, and (2) to remove secretions in the lower airway that result from coma and convulsions.

There were two patients with tetanus in whom tracheotomy was used. One of these patients, a five-year-old child, died from the effects of severe tetanus. Tracheotomy was delayed until the tenth day of illness and the patient died on the day following the operation. The other patient, a two-year-old child, had emergency tracheotomy performed because of severe respiratory obstruction, dyspnea, and cyanosis present on entrance to the hospital. Following tracheotomy the patient was found to have mediastinal emphysema and minimal pneumothorax on chest roentgenograms. Neither of these conditions required treatment and the child recovered after almost two weeks of continuous, intensive treatment. Recovery would have been impossible without tracheotomy.

Neurosurgical operations and head injury (56 cases). Tracheotomy was used for disturbances of respiratory physiology and secretional obstruction after head injury in 32 patients and following extensive neurosurgical operations in 24 patients. The use of tracheotomy in these cases is based on essentially the same principles followed in poliomyelitis and similar cerebral diseases.

Secretional obstruction in patients with head injuries and following neurosurgical operations may result from several closely related mechanisms. First, there may be coma or partial loss of consciousness with loss of the central response to the cough reflex. Second, intrinsic lesions of the cranial nerve nuclei and medullary centers may result from tumors, infection, or hemorrhage and may produce dysfunction of the coordinated movements necessary for swallowing and coughing. This mechanism is quite similar to that of bulbar poliomyelitis. Third, there may be trauma or compression of the midbrain and medulla which results in central respiratory weakness and failure. Fourth, increased intracranial pressure is believed to be associated with increased pulmonary secretions.

As pointed out by Echols *et al.*[82] and others,[35, 78, 197, 244, 259, 272] provision for a clear airway and adequate cerebral oxygenation is the foundation for treatment in these cases. Unless the devastating combination of damaged cerebral and medullary tissues under low oxygen and high carbon dioxide concentrations can be averted, other steps in treatment may well be worthless. All too frequently a brilliantly conceived and executed neurosurgical operation may be doomed to failure because of avoidable pulmonary complications.

In perhaps no other clinical case group was the need for tracheotomy so great. It was discovered in these cases that more conservative measures for clearing the airway were entirely inadequate. The inadequacy of these measures is best pointed out by the fact that hidden pulmonary secretions, which had not previously been disclosed despite vigorous aspiration, were obtained following

tracheotomy. Tracheotomy was found to be the only means of clearing the airway that met all the patient's needs, both for immediate treatment and for latter care in long term illnesses. The indications for tracheotomy in this patient group were: (1) for removal of secretions; (2) in any comatose patient; (3) in any patient with respiratory failure; and (4) in patients with increased intracranial pressure and manifesting signs of cardiorespiratory instability.

Clinically, three distinct types of cases with cerebral damage were recognized. The case fatality rate was closely related to these clinical types. First, there were 28 patients whose chief difficulty was retained secretions and in whom, initially, neither coma nor respiratory failure was present. The case fatality rate was 39 per cent. Second, there were 16 patients with secretional obstruction who were deeply comatose. The case fatality rate was 81 per cent. Third, 12 patients had retained secretions, plus coma, plus respiratory weakness or failure. Every one of these patients died. The over-all case fatality rate in these 56 patients was 64 per cent, which, as just pointed out, was quite closely related to the severity of cerebral damage. The greatest value of tracheotomy was not in saving an occasional life in the hopelessly injured patient, of which there were many, but in preventing death from cerebral anoxia in patients with only moderate brain damage and in clearly distinguishing the effects of respiratory anoxia from those of cerebral trauma. If improvement did not occur after tracheotomy, severe cerebral and medullary damage was usually present.[197]

The advantages of tracheotomy in patients with brain injury from trauma or operation were: (1) maintenance of a clear airway; (2) the creation of a vent to diminish the transmission of increased intrathoracic pressure to the cranial cavity;[78] (3) for use in artificial respiration; and (4) for use in anesthesia on patients with combined head and facial injuries.

There were 12 patients in whom the tracheotomy opening was used as a means of controlled respiration. In nine of these patients respiration was maintained artificially by means of an automatic intermittent positive pressure apparatus, the pneophore (figure 10). In three patients respirations were controlled manually by means of an anesthesia machine. In either instance the tracheotomy cannula must be replaced by an endotracheal tube with an inflatable cuff. None of the patients who required controlled respiration survived. Two patients out of the twelve regained spontaneous respirations but died later, one of hemorrhage from esophageal varices, the other from complications of the tracheotomy. The latter patient seemed well on the way to recovery after an operation for epidural hematoma. Eighteen hours after controlled respiration had been discontinued, the patient asphyxiated suddenly. At autopsy a large mucus plug was found extending from the larynx into the trachea and completely occluding the tracheotomy cannula (figure 7). Other complications noted in this patient group were infection of the tracheotomy wound occurring two weeks after decannulation in one patient and pneumothorax in one patient; and the use of the respirator had to be abandoned in one patient because of a low tracheotomy.

Thoracic operations and injuries (29 cases). Operations and injuries of the chest, by their very nature, are apt to interfere with the normal self-cleansing mecha-

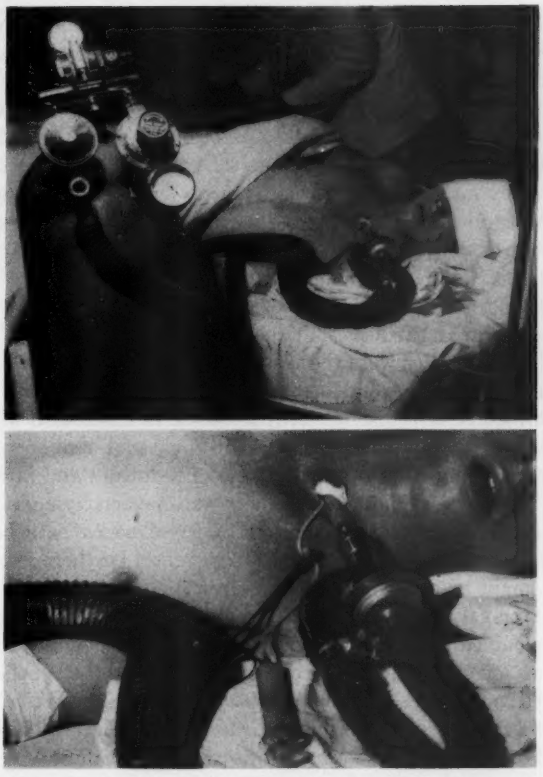

FIG. 10. Use of a pneophore for prolonged artificial respiration in a patient with severe head injury. This apparatus provides a respiratory cycle of nearly any depth and speed desired, but has many disadvantages. Airtight connections are required for efficient operation, there is limited access to the airway, and respiration is maintained entirely in the positive pressure range.

nism of the respiratory tract. In either condition, the altered respiratory physiology that results is quite similar. The causes for these physiologic alterations following injury or operation to the chest include: (1) increased secretions, (2) decreased ability to clear secretions, and (3) decreased efficiency of the thoracic bellows system. An increase of fluid in the respiratory tract may result reflexly from chest wall trauma,[74] influx of blood from the upper respiratory passages or from injured lung, and from aspirated saliva and gastric contents. Blood and gastric fluid are both marked irritants to the respiratory mucosa, and may cause an outpouring of secretions and bronchospasm. In addition, blood may form tenacious clots which are difficult to expel.[276] The over-all effect is to overload the tracheobronchial tree in a patient poorly equipped to cope with the insult. The decrease in the patient's ability to clear his tracheobronchial tree results from thickening of the secretions and bronchospasm, from unwillingness to cough

because of incisional or traumatic pain, and from inability to cough efficiently because of disruption of the normal integrity of the chest wall.[38] A decrease in efficiency of the thoracic bellows system may result from multiple rib fractures, extensive thoracoplasty, injuries of the diaphragm, and the presence of abnormal fluid or air in the pleural space. Both the ability to cough and to ventilate properly may be severely impaired. It is apparent that these deficiencies from thoracic trauma are closely interrelated and the tendency for a vicious cycle is great.

In 1945, the clinical state that results from these traumatic alterations in respiratory physiology was described as "wet lung" by Burford and Burbank.[38] They and other writers[32, 238] emphasized the frequent occurrence of secretional anoxia as a dangerous consequence of both penetrating and blunt injury to the thorax in World War II battle casualties. All these writers stressed that dyspnea, cyanosis, and audible râles were the result of a painful, weak, ineffectual cough and inefficient respiratory excursions. Brewer and his co-workers[32] remarked on the extreme difficulty of resuscitation from shock in cases with wet lung unless active measures were taken. The treatment suggested was encouragement of coughing, relief of pain by the judicious use of sedatives and intercostal nerve block,[232] and correction of paradoxical chest wall motion by splinting and traction.[21, 22] Retained secretions were removed by intratracheal catheter suction and occasionally by bronchoscopy. In none of these reports is there a suggestion that tracheotomy might be of advantage in the treatment of traumatic wet lung.

In 1950 Baronofsky[13] first reported the clinical use of tracheotomy in chest injuries. It remained for Carter,[40] however, to clearly define the exact role of tracheotomy in severe injuries of the chest. He described the benefits of tracheotomy as twofold: mechanical, for the purpose of aspirating secretions, and physiologic, to decrease resistance to inspired air and to decrease the respiratory dead space. The use of tracheotomy for physiologic benefits in chest injuries represents a novel and somewhat neglected approach. Carter postulated that most of the resistance to breathing occurs in the upper air passages and that a bypass of this area should result in easier respiration. He found that this concept was substantiated by a reduction in the intratracheal and intrapleural pressures following tracheotomy. Clinically, the elimination of this bottleneck is reflected in a rather dramatic lessening of the paradoxical movement of a loose segment of the thoracic wall. The greater ease of respiration and reduction of the painful movement of fractured ribs are potent factors in survival of these patients. In addition, Carter discovered that tracheotomy resulted in the elimination of approximately 100 cc. of dead space in the upper air passages. In a normal subject with a tidal air volume of 500 cc., this dead air, which does not contribute to oxygenation, is tolerated without difficulty. In patients with marginal ability to ventilate and reduction of the tidal air volume, this constant dead air volume becomes more and more detrimental to ventilation. After tracheotomy, the elimination of the major part of the dead air space results in a more efficient utilization and oxygenation of the reduced tidal volume.[24, 40, 41, 42] These benefits are graphically illustrated in figure 11. It would seem that this important physiologic benefit of tracheotomy would be equally important in any form of ventilatory distress wherein the flow of tidal air is decreased.

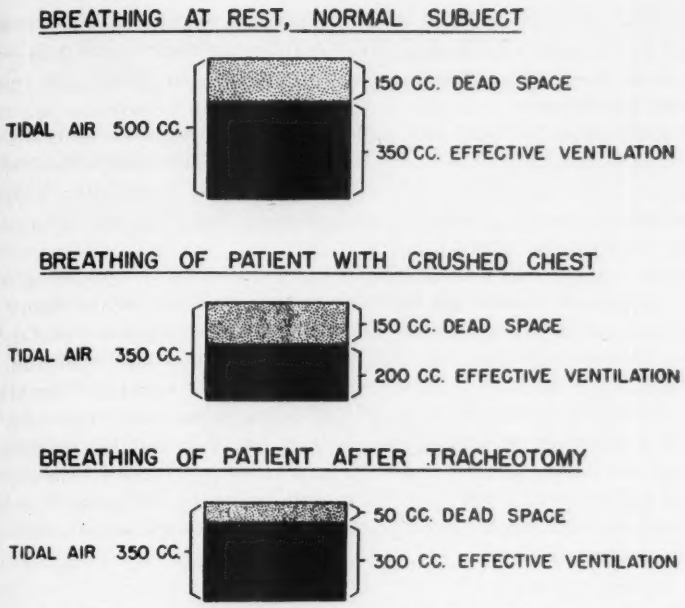
BREATHING AT REST, NORMAL SUBJECT
TIDAL AIR 500 CC.
150 CC. DEAD SPACE
350 CC. EFFECTIVE VENTILATION
BREATHING OF PATIENT WITH CRUSHED CHEST
TIDAL AIR 350 CC.
150 CC. DEAD SPACE
200 CC. EFFECTIVE VENTILATION
BREATHING OF PATIENT AFTER TRACHEOTOMY
TIDAL AIR 350 CC.
50 CC. DEAD SPACE
300 CC. EFFECTIVE VENTILATION

FIG. 11. Graphic demonstration of improved ventilation in chest injuries after tracheotomy. (From Carter, B. N.[49, 41])

In this group of 29 patients with diminished respiratory reserve following thoracic surgery or trauma, every important benefit of tracheotomy noted by other writers was observed. An additional benefit of tracheotomy, not previously described, was also noted. In two patients tracheotomy was performed following difficult pulmonary resections in order to prevent closed glottis pressure on a precarious bronchial stump closure. It was conceived that tracheotomy would not only aid in prevention of disruption of the bronchial suture line, but would provide ready access to secretions without undue stimulation of coughing. In each of these patients the described effects were obtained; in fact, the postoperative course in these two patients was much smoother than would have ordinarily been anticipated following such difficult surgery.

Briefly summarized the benefits of tracheotomy in chest injuries and following major thoracic surgery are: (1) Mechanical—bypass an obstruction, and remove retained secretions. (2) Physiologic—decrease resistance to breathing, decrease respiratory dead space, and prevent closed glottis pressure on a precarious bronchial stump closure.

Chest injuries (16 cases):—The majority of these injuries were the result of automobile accidents. Two patients had penetrating gunshot wounds. All 16 patients had secretional obstruction of the airway to some degree. Twelve pa-patients had multiple fractures involving the ribs, clavicles, or sternum. Of these 12 patients, eight had moderate to marked flail or paradoxical movement of the chest wall. A striking reduction of the flail movement was obtained follow-

ing tracheotomy in six patients, while two patients required skeletal traction in addition to tracheotomy. The improvement following tracheotomy was reflected in an almost immediate reduction of the respiratory rate, relief from pain, and improved ventilation.

In eight patients the chief problem in management was retained secretions as manifested by audible râles and radiologic evidence of pulmonary infiltration and atelectasis. The tracheotomy allowed easy removal of secretions without producing painful episodes of retching and coughing that occurred when an intratracheal catheter was passed.

Thoracic surgery (13 cases):—In 11 cases tracheotomy was performed for relief of secretional obstruction following thoracic or thoracoabdominal surgery. Six patients had pulmonary resections, while five had esophageal surgery. In two patients tracheotomy was performed to prevent closed glottis pressure on a precarious bronchial stump. There were seven deaths in this group, of which three were newborn infants who died of pulmonary complications following repair of a tracheoesophageal fistula. In the group of chest injury patients there was only one death, which was due to fat embolism. The case fatality rate in these 29 patients was 28 per cent. There were no deaths associated with the use of tracheotomy and only one complication, that of bleeding from the tracheotomy wound, postoperatively.

Special Uses for Tracheotomy

The tracheotomy opening was used as a simple and accessible route for bronchoscopy 22 times, for the administration of endotracheal anesthesia 79 times, and for use in respiratory resuscitation 24 times.

Bronchoscopy was employed through the tracheotomy opening for removal of retained secretions, blood clots, and mucus crusts, when relief could not be obtained by aspiration through the cannula. Again, the advantage of excising a portion of the anterior tracheal wall was demonstrated by the easy transfer of instruments without loss of the airway. Bronchoscopy through this route is technically simpler than the usual method since the administration of topical anesthesia and passage of the instrument are both less burdensome to the patient (figure 12). The use of bronchoscopy in association with tracheotomy is probably best demonstrated by the following case report of a six-year-old boy with acute laryngitis complicated by aspiration of vomitus (figures 13 and 14).

CASE REPORT

Section 1, figure 13, shows the appearance of the chest roentgenogram on admission. Note the marked bilateral pulmonary infiltration and especially note the tremendous gastric dilatation which so frequently occurs in children with severe dyspnea. Immediate bronchoscopy was performed, and because of edematous obstruction at the larynx, tracheotomy was performed over the bronchoscope. Section 2 of figure 13 shows the chest x-ray after removal of a large amount of thick secretions mixed with gastric contents. Immediate improvement of the patient was gratifying, but 12 hours later the child again was in distress, although the chest x-ray (section 3, figure 13) revealed little change other than the suggestion of early emphysema of the left lung field as compared to the right. A few hours

later, the child appeared almost in extremis. Chest roentgenograms taken in inspiration and expiration (section 4, figure 13, and section 5, figure 14) revealed almost no change in position of the diaphragm and intercostal spaces. Marked bilateral obstructive emphysema was present. Bronchoscopy was again performed and almost an entire case of the tracheobronchial tree, composed of thick secretions and clotted blood, was removed. The child fell asleep with the bronchoscope still in place. The following afternoon the patient again had moderate respiratory distress and elevation of pulse and temperature. The chest roentgenogram (section 6, figure 14) revealed the typical findings of left lower lobe atelectasis with a double cardiac border on the left associated with minimal infiltration near the apex of the heart and compensatory emphysema of the upper lobe. Bronchoscopy was again

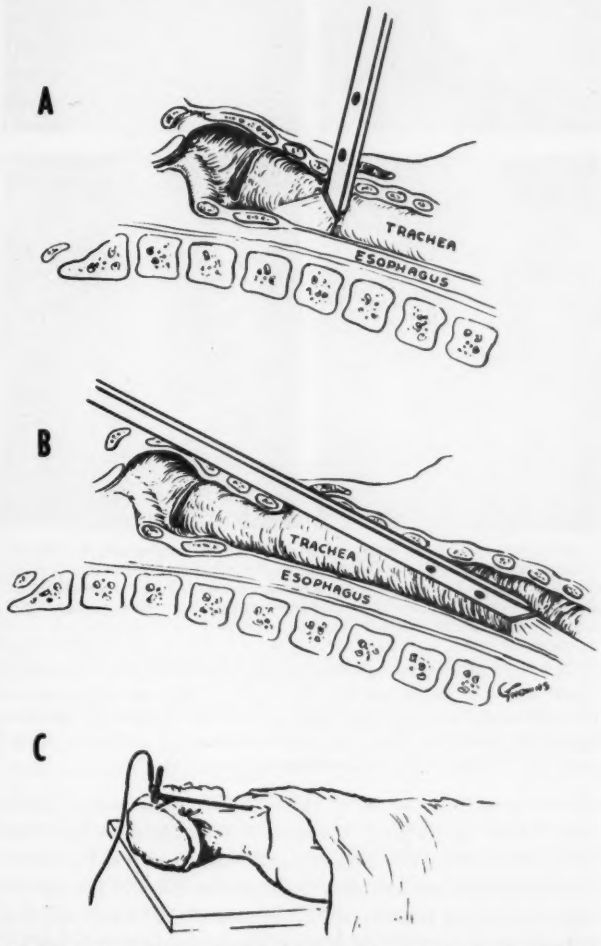

FIG. 12. Technic of bronchoscopy through the tracheotomy opening. After topical anesthesia is administered, the cannula is removed and the bronchoscope introduced (*A* and *B*). The examination is facilitated by turning the patient's head to the left and may be performed either in the supine or semi-erect position (*C*).

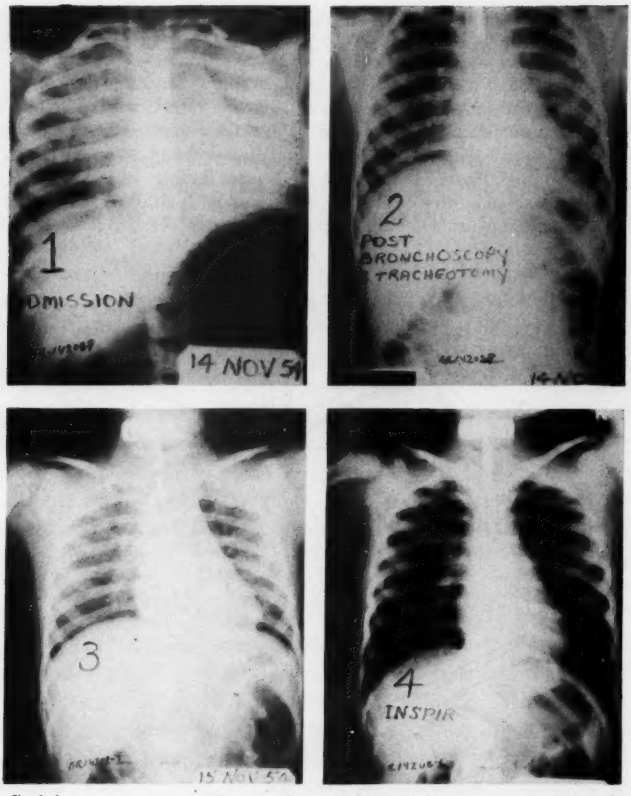

FIG. 13. Serial roentgenograms in a patient with acute laryngotracheitis and secretional obstruction from aspiration of vomitus. (*1*) Note bilateral pulmonary infiltration and marked gastric dilatation (*2*) Clearing after bronchoscopy and tracheotomy. (*3*, *4*, and *5*) Progressive development of bilateral obstructive emphysema. Note widening of intercostal spaces and absence of diaphragmatic motion in *4* and *5*.

performed through the tracheotomy opening, with removal of thick mucus and pus blocking the left lower lobe bronchus. Bronchoscopy was repeated later that same day and additional thick secretions and several mucus crusts were removed (section 7, figure 14). Improvement was progressive from this time on. Section 8, figure 14, reveals a normal-appearing chest x-ray just before removal of the tracheotomy cannula.

Endotracheal anesthesia was given through the tracheotomy opening both in the initial and follow-up surgical management of patients with burns, maxillofacial injuries, head and neck tumors, and head injuries. In cases of maxillofacial injury or burns the tracheotomy was used repeatedly for anesthesia during multiple stages of surgical reconstruction (figure 15). The endotracheal tube can be passed without the hazards of deep anesthesia or muscle relaxants. A high flow of oxygen and light planes of anesthesia are maintained; the patient awakes readily and is able to take nourishment almost immediately. The hazards of

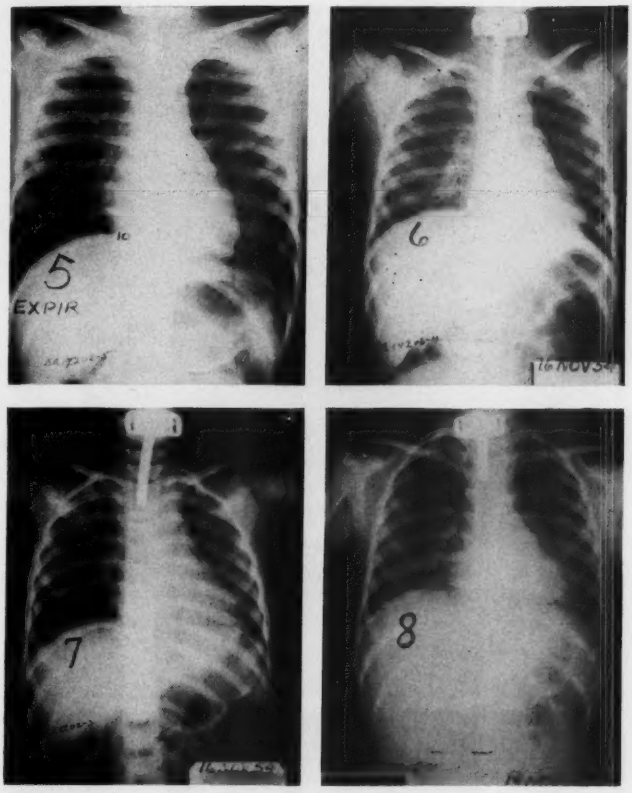

FIG. 14. Serial roentgenograms in a patient with acute laryngotracheitis. Bronchoscopy performed after *5* with removal of a complete cast of the upper tracheobronchial tree composed of clotted blood and mucus. Later (*6*) atelectasis of left lower lobe diagnosed from double cardiac border on left and compensatory emphysema of left upper lung field. Bronchoscopy again performed with removal of mucus and pus from lower lobe bronchus. After *7* bronchoscopy again performed and a large crust removed from left main stem bronchus. In *8* the appearance is shown just before decannulation on the fifth day of illness.

aspiration are greatly reduced with a tracheotomy, so that nutritional feedings can be supplied almost without interruption, even in the face of multiple operations. This is a factor of greatest practical importance in the treatment of severely burned patients.

Tracheotomy was found to be an effective means of respiratory resuscitation in patients with respiratory failure associated with head injuries, barbiturate poisoning, neurosurgical procedures, and apnea following tracheotomy. In an emergency, respiratory exchange can be maintained with a simple device consisting of a rubber tube leading from a source of oxygen and inserted into the tracheotomy opening (figure 16). A side vent in the rubber is provided to break the flow of oxygen so that inspiration and expiration can be simulated closely. A

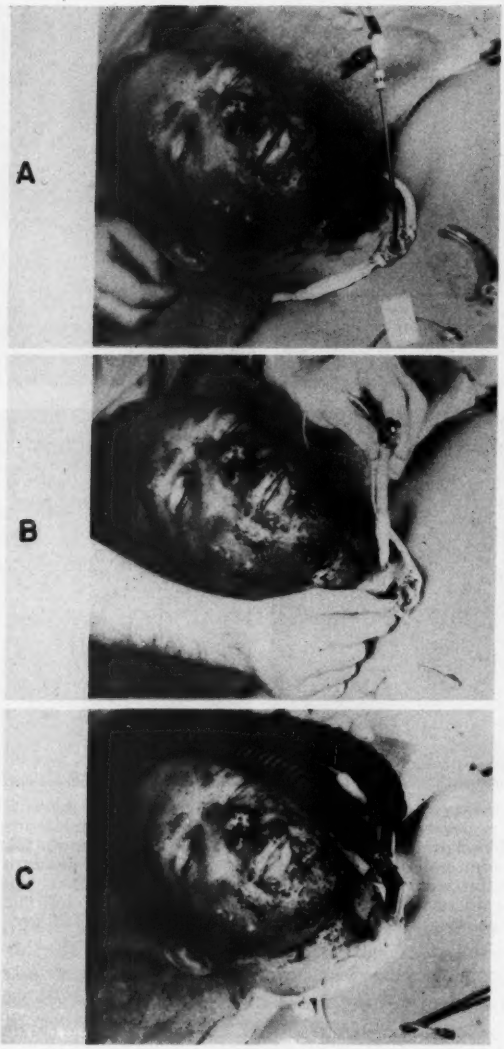

FIG. 15. The technic of endotracheal anesthesia through the tracheotomy opening. *A* shows administration of topical anesthesia of trachea using a simple hand spray. *B* shows replacement of cannula with endotracheal tube. If the excision technic has been used, there is less danger of losing the airway at this point (see figure 23). *C* shows anesthesia in progress. Note that no anesthetic gases or apparatus need contact the burned areas.

high rate of oxygen flow is necessary because of leakage around the cannula, which can be diminished by placing a gauze pack in the pharynx or by placing the hand over the nose and mouth. This method was found to be very effective in cases of cardiac arrest occurring outside the operating room. Emergency

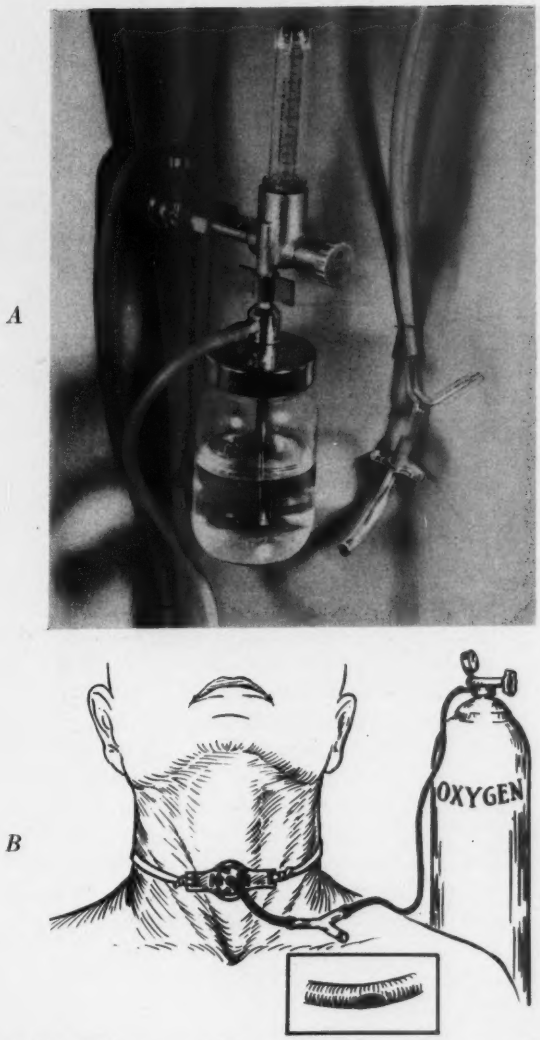

FIG. 16. *A* (top) shows the apparatus for emergency respiratory resuscitation used with a tracheotomy. Note rubber catheter placed in tracheotomy cannula (the large end of an ordinary French catheter serves admirably well) and the Y-shaped glass connector to vent the flow of oxygen. *B* (bottom) shows the apparatus in use connected to a tank of oxygen. The inset demonstrates that a hole in the side of the rubber tubing will also serve as a vent. Inspiration and expiration can be simulated closely by the make and break flow of oxygen provided with this simple apparatus.

tracheotomy was performed as the chest was opened and expansion of the lung maintained until an endotracheal tube could be obtained. This method, of course, is temporary and best suited for emergencies. If further artificial respiration is needed, the cannula is replaced by an endotracheal tube, which is then connected

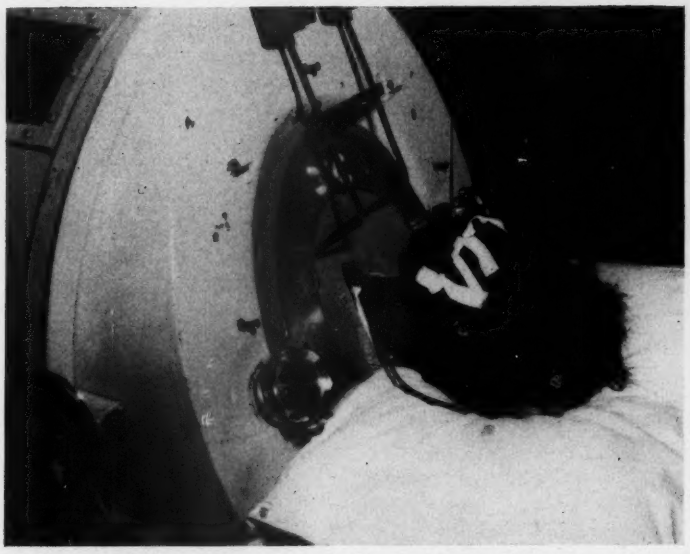

FIG. 17. Patient with tracheotomy in a Drinker respirator. Note the new type slanting front respirator which provides easier access to the tracheotomy opening.

to an automatic intermittent positive pressure device, the pneophore (figure 10). Controlled respiration may be maintained for hours, if necessary. However, due to the fact that respiration is maintained in positive pressure throughout both phases of the respiratory cycle, mediastinal emphysema, overdistention and destruction of alveolar sacs, and extreme drying of the respiratory mucosa occur with prolonged use of this method. In addition, there is no provision for liberation of carbon dioxide and extreme respiratory acidosis may occur. The anesthesia machine may be used for artificial respiration, but requires the constant attention of an anesthetist. The tank respirator is the most satisfactory method of maintaining artificial respiration for prolonged periods since the disadvantages just mentioned can be avoided, and there is constant access to the airway through the tracheotomy opening (figure 17).

Technic of Tracheotomy

Applied anatomy. Nearly every important anatomic landmark for the surgical approach to the trachea is available for study by palpation and without dissection (figure 18). The field of the operation is bordered by the thyroid cartilage and its prominence superiorly, the sternum and suprasternal notch inferiorly, and the medial edge of each sternocleidomastoid muscle to either side. Roughly, this area is equivalent to the "triangle of safety" as described by Jackson.[152] Between 1 and 2 cm. below the thyroid cartilage prominence is another point of resistance and protrusion, the cricoid cartilage. Between these two prominences is a small quadrilateral space, a depressed area measuring 1 cm. across, the cricothyroid membrane. Immediately below the cricoid cartilage, the upper tracheal rings are

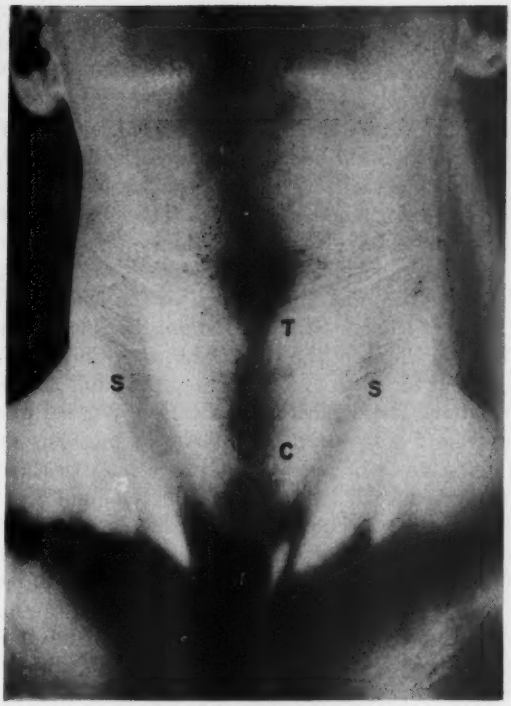

FIG. 18. Topography of neck used for tracheotomy. The thyroid (*T*) and cricoid (*C*) eminences are prominently displayed with the cricothyroid space between. To either side is the sternocleidomastoid muscle (*S*), and the jugular notch (*J*) is shown below.

readily palpable, but inferiorly it becomes increasingly difficult to differentiate the rings from each other. At the level of the suprasternal notch, the trachea lies 1 to 1½ cm. deeper than at the level of the cricoid cartilage, due to the posterior inclination of the trachea as it descends into the chest. In children, all these measurements are reduced by at least one-half, but the gross anatomic relationships are constant. Immediate orientation of the surgical field for tracheotomy is possible by practice in palpation of this area, and from this information alone the optimum area for surgical exposure of the trachea can be determined.

A review of the technic of tracheotomy advised by many authors[88, 94, 98, 138, 139, 152, 188, 200, 270] reveals that there are three main points of difference in the advocated surgical approach to the trachea. These are: (1) the skin incision, (2) the treatment of the thyroid isthmus, and (3) the location for entrance into the trachea. The same differences of technic were apparent in the analysis of the 310 tracheotomies of this study.

Fourteen cadavers, seven adults and seven children, were selected for study of these factors in technic. A deliberate effort was made to select subjects with differences in bodily habitus.

As far as could be determined, the transverse skin incision, when suitably

undermined and retracted, gives a vertical linear exposure approximating two-thirds of the same length vertical incision. Transverse and vertical skin incisions exactly 4 cm. in length were made on three each of six adult cadavers. There was no essential difference in exposure if the incisions were of this length. However, if the vertical incision was extended to 6 or 8 cm. in length, then transverse incisions up to 10 cm. with wide undermining were necessary to approach the same exposure. Since by actual surgical experience such lengthy incisions have been found unnecessary, for practical purposes there is no difference in surgical exposure through either of these types of incisions.

Even in this limited sample a surprising anatomic variation was found in the position and size of the thyroid isthmus and in the length of trachea in the neck. With the neck in moderate hyperextension (the plane of the face at 45° to the horizontal), the length of the trachea between the cricoid cartilage and the suprasternal notch varied from 4 to 7 cm. in the adult and from 2 to 5 cm. in infants and children. The number of tracheal rings varied from five to eight in the adult and from five to seven in children. In most instances rather extreme hyperextension was required to bring more than the fifth tracheal ring into the normal surgical field. In only two subjects would incision below the fifth tracheal ring have been technically feasible. In one of these subjects a cannula was placed through rings five and six, but on return of the neck to normal position the cannula was found to be awkwardly placed and prone to fall out. In addition to the trachea being deeply placed at this level, the number and size of adjacent veins are increased in this area. It would seem that the optimum location for the tracheotomy opening should lie above the fifth tracheal ring, since operative hazards and technical difficulties are increased below this level.

There is conflicting advice as to how the thyroid isthmus should be handled. Some advise retraction;[94, 98, 256, 290] some advise division.[45, 76, 88] In the analysis of the technic in these 310 tracheotomies, it was obvious that some surgeons took great pains to avoid cutting the thyroid isthmus. In certain instances this led to a poorly placed cannula and postoperative difficulties. In the 14 cadaver subjects, the thyroid isthmus in adults measured from 1 to 3 cm. in width and covered up to four tracheal rings. In children the isthmus averaged about 1 cm. in width and usually covered the first, second, and third or second, third, and fourth rings. In nearly every specimen the thyroid isthmus covered all or part of the optimum area for a tracheotomy opening. In every specimen where a cannula was placed through the third and fourth rings with the isthmus retracted there was tendency for the tube to be shoved out of position when the isthmus was released. An even greater source of danger was also noticed. When the cannula was removed the isthmus promptly covered the tracheotomy opening. It would seem then that, more often than not, the thyroid isthmus will cover the normal tracheotomy site. The surgeon should not make efforts to avoid or retract the isthmus but should be prepared to bisect it as a necessary part of the procedure. Jackson's advice[152] that the thyroid isthmus should be entitled to no consideration whatsoever in determining the location for tracheotomy still holds true. Further discussion of the locations and types of tracheal openings will be given in Chapter IV.

The position of the patient for any type of tracheotomy is of greatest im-

portance. All authors[117, 135, 139, 219, 256, 280] agree that the neck should be placed in the hyperextended position so that the trachea is extended, becoming more superficial, and there is more length of trachea available in the neck. Digby[76] has advocated extreme hyperextension so that the trachea can be better exposed during emergency operations. It has been the personal experience of the author that many patients with respiratory distress do not tolerate extreme hyperextension of the neck. This is believed to be due to a reduction of vital capacity and tidal air exchange associated with this position. In each of four healthy adults the vital capacity was tested several times with the neck in both normal and hyperextended positions. A constant reduction of vital capacity from 300 to 450 cc. of air was effected by marked hyperextension of the neck. In addition, the increase in length of trachea from the cricoid cartilage to the suprasternal notch was measured, comparing the effect of moderate and extreme hyperextension. From the average of 20 measurements made in both living and cadaver subjects, a gain in exposure of approximately one tracheal ring, less than 1 cm., was observed. The advantage gained from extreme hyperextension was considered negligible.

The importance of placing the patient so that the nose, chin, and suprasternal notch are in the same median plane has been stressed.[152, 256, 261] Examination of six normal adults revealed that turning the head to one side could produce a deviation of the prominence of the thyroid cartilage from the median plane by as much as 3 cm. In addition, that important landmark, the cricoid cartilage, could be rendered almost impalpable by such a maneuver.

Analysis of clinical material. The technical details of the 310 tracheotomies in the present study are shown in table 5. The operations were divided into three types: elective, urgent, and emergency. This separation is based on the degree of respiratory distress of the patient or on the surgeon's statement as to the type of operation. The latter method was not always reliable since there was a great tendency for the surgeon to classify the operation as an emergency, although the time lapse of the operation was as much as 20 minutes.

Operations were classified as emergency if there was little time allowed for anesthesia or sterility. The true emergency nature of these operations is evidenced by the fact that in 28 of the 48 emergency operations no anesthesia was used. Elective operations were those in which ample time was allowed to decide upon and perform the operation. Of the 310 operations, 200 were elective procedures. Certain operations could be fitted into neither of these categories and were arbitrarily termed urgent. In these 62 instances there was generally time to obtain anesthesia, suitable draping, and the use of assistants and retractors, but further delay, as for example, to observe the patient or move him to the operating room, was not considered safe. It was in this group of patients that the use of the bronchoscope for a positive airway during tracheotomy was of great value in reducing the urgency of the situation. It was interesting that the locale of the operation many times had little to do with the type of operation. Some of the gravest emergencies occurred with the patient in the operating room, while many elective tracheotomies were performed, by choice, with the patient in bed.

The marked preference for the technic using a vertical skin incision and a

TABLE 5

Classification of technical details in 310 tracheotomies (1947–1955)

Technical Details	Number	Percentage
Type of operation		
Elective	200	65
Urgent	62	20
Emergency	48	15
Skin incision		
Vertical	248	80
Transverse	62	20
Tracheal incision		
Vertical	224	72
Cruciate	28	9
T-shaped	12	4
Excision	46	15
Anesthesia		
Local	248	80
General	34	11
None	28	9
Preoperative airway		
Bronchoscope	22	7
Endotracheal tube	9	3
Tracheal anesthesia	56	18

vertical slit in the trachea is shown in table 5. The transverse skin incision was used more in recent years and more often by general surgeons. The author has found the transverse skin incision, by actual practice, to pose no technical disadvantages, since in elective operations exposure is virtually the same, and in emergency operations, using the "feel" technic, visual exposure of the trachea is neither necessary nor advantageous. The chief advantages of the transverse incision are a better cosmetic appearance on healing and a reduced tendency for a densely adherent "bow-string" type scar seen more often with vertical incisions (figure 19). With either type incision, the length of time the cannula was left in place was a definite factor in producing an unsightly scar (figure 19). The chief disadvantages of the transverse incision are that there is more of a tendency for pooling of secretions within the wound and, if the incision is improperly placed, the cannula may be pushed out of optimum position.

In the more recent years of the period of this study there was noted a growing tendency to excise a portion of the anterior tracheal wall, or at least to make a T-shaped or cruciate incision into the trachea, rather than to use the vertical slit. The clinical advantages of excising a piece of trachea to make room for the cannula are numerous. If the cannula becomes dislodged or needs to be replaced with another cannula, a bronchoscope, or an endotracheal tube, the airway is more satisfactorily maintained during the period when the cannula is out. The clinical and experimental work to be cited subsequently has revealed that it requires up to five days for a permanent fistula to form. During that time the edges of any incised tracheal wound will approximate promptly if the cannula

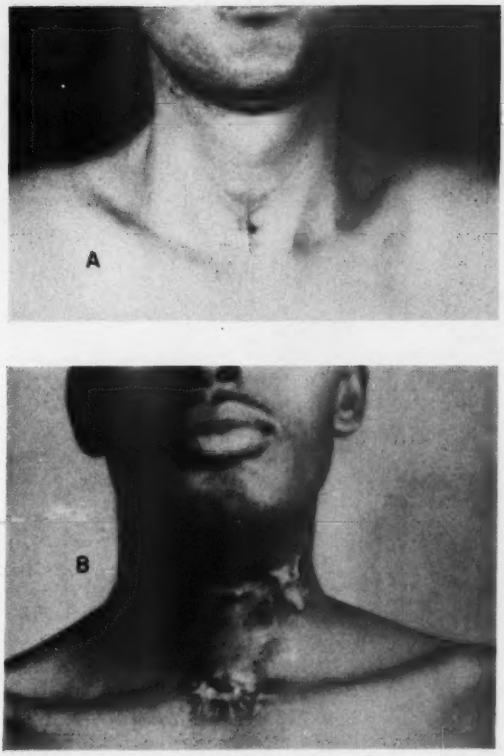

FIG. 19. Healed tracheotomy scars. In *A* note the "bow-string" type of scar resulting from vertical incision. *B* shows that a transverse incision does not always give a good cosmetic effect, particularly if placed too low and the cannula is worn for a prolonged period.

becomes dislodged (figure 20). Many episodes of respiratory difficulty and at least one death were the result of disregarding this factor. There were no complications nor delay in healing using the technic of excision.

The preference for local anesthesia in these 310 operations is evident also in table 5. General anesthesia is not recommended for any tracheotomy unless a positive airway can be assured during the operation. At least 90 per cent of the tracheotomies performed under general anesthesia were in association with another operation for which anesthesia was already in progress. The endotracheal region was infiltrated with local anesthesia before incision 56 times in this series of 310 operations. This technical variation adds little to the operation, although it does lessen somewhat the paroxysm of coughing associated with cutting the trachea and placing the cannula. The use of local infiltration was formerly considered a technical point of great value for performing "tranquil" tracheotomy.[262] More often than not it is desirable that the cough should be stimulated rather than depressed.[152]

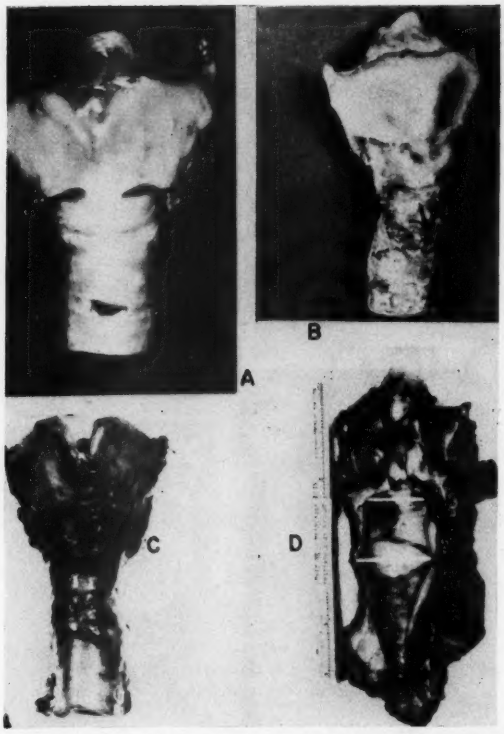

FIG. 20. Types of tracheal incisions, all demonstrated on fifth postoperative day. In *A* (upper left) the excision method provides a continuously patent opening while in *B* (upper right) and *C* (lower left) the cruciate incision is partially patent and a true fistula is just forming. *D* (lower right) the vertical incision, approximates closely when the cannula is removed.

Recommended technic. The recommended technic for tracheotomy is based on the clinical advantages and anatomic features just described. Several points in technic are common to any type of tracheotomy and will be considered first. The patient should be placed with the neck in moderate, not extreme, hyperextension and with the nose, chin, and suprasternal notch in the median plane. Local anesthesia only should be used. Preliminary orientation by palpation of the anatomical landmarks should precede the incision.

Cricothyroidotomy (figure 21):—Although cricothyroidotomy was not performed once in these 310 tracheotomies, and is rarely indicated as a substitute for emergency tracheotomy, there are desperate situations in which the operation will be lifesaving.[219, 225, 279]

The cricothyroid space is carefully located between the thyroid and cricoid cartilages and a transverse opening made into the airway with a scalpel, penknife, or any available sharp instrument. The opening may be held open by sutures, pins, or paper clips attached to adhesive tape or rubber bands for traction. A soft

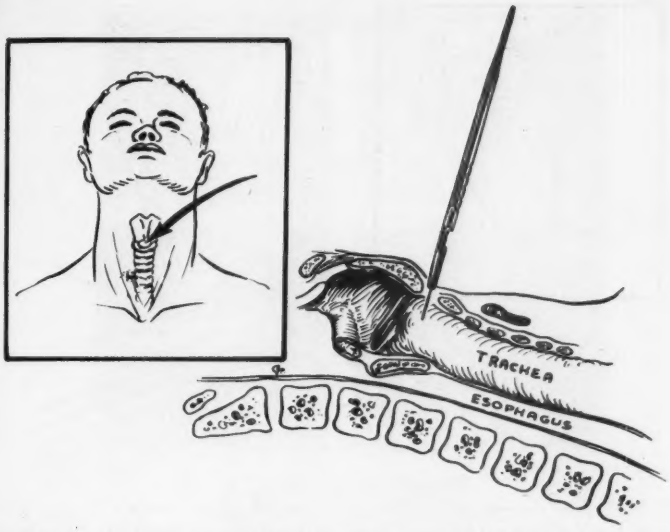

FIG. 21. The technic of cricothyroidotomy. The cricothyroid space is carefully located (see figure 18) and the skin and cricothyroid membrane cut transversely in one motion. The knife blade or handle is twisted to open the incision, which is kept open by any means at hand.

rubber catheter may be placed into the opening for aspiration of secretions and for an airway, if desired. In general, and especially in children, a tracheotomy cannula should not be used for fear of damage to the cricoid cartilage. If a continued airway is needed after the immediate emergency or a tracheotomy cannula has been used for as much as several hours, elective tracheotomy should be performed.

Emergency tracheotomy (figure 22):—The most common mistake made in the performance of emergency tracheotomy in this series of patients was the loss of valuable time by the surgeon in efforts to gain visual exposure of the trachea. The personal experiences of the author either as surgeon or first assistant in over 10 per cent of the tracheotomies in this series, and analysis of the clinical records which denoted the time lapse for execution of the operation by other surgeons, clearly demonstrated that the method for emergency tracheotomy described by Jackson in 1904[139] has yet to be improved upon. As pointed out by Jackson, emergency tracheotomy is a "feel" operation rather than a "sight" operation. As shown in figure 22, a small vertical (or transverse) skin incision is made centered at a point midway between the cricoid cartilage and the suprasternal notch. With short positive strokes of the knife, guided by the opposite index finger, vertical dissection is made through the strap muscles and thyroid isthmus until the trachea can be palpated and oriented. The trachea is then entered vertically well below the cricoid cartilage, still guided by the forefinger of the opposite hand. Two or three tracheal rings are cut, the cannula is slipped in by feel,

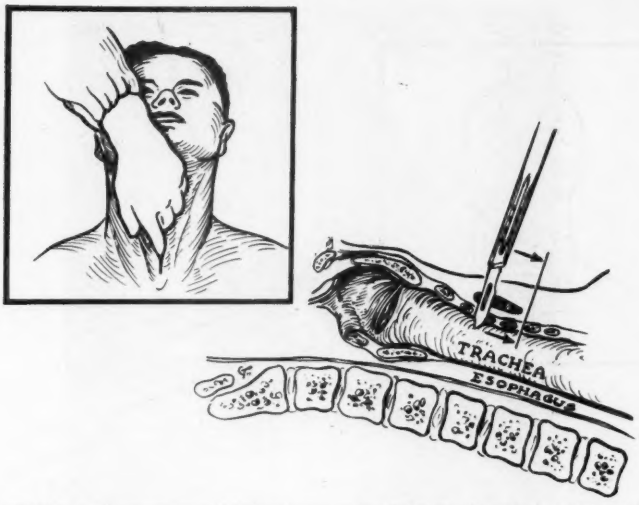

FIG. 22. Technic of emergency tracheotomy using the "feel" technic. A short incision is made and by sharp dissection the trachea is "exposed" to the palpating index finger. The trachea is entered well below the cricoid cartilage, at least two rings are incised, and the cannula is slipped in.

checked by feel, and the wound is packed with gauze for hemostasis. Using this technic, the author has completed the operation in less than 40 seconds from the time the knife was in hand.

Elective tracheotomy (figure 23):—In brief, the recommended technic includes a transverse skin incision, division rather than retraction of the thyroid isthmus, and excision of a portion of one or more tracheal rings from the second through the fifth ring. Figure 23*A* shows a 4-cm. transverse skin incision centered between the cricoid cartilage and suprasternal notch. The patient is in a position of moderate hyperextension of the neck. Figure 23*B* shows the thyroid isthmus exposed after the strap muscles have been separated in the midline and retracted. In figure 23*C* the thyroid isthmus has been divided between ligatures exposing the cricoid cartilage and the first tracheal ring. In figure 23*D* a portion of the third tracheal ring has been excised. Figure 23*E* shows the cannula in place. On a square of gauze to one side is the portion of excised cartilage.

Aftercare

Proper aftercare of the patient with a tracheotomy has but one major purpose: to keep both the natural and artificial airways open.[63, 139, 229] In perhaps few other operations is violation of the principles of postoperative care so often attended by loss of life just saved by a skillfully executed operation. Also, there are few other operations in which major complications are so frequently the result of postoperative mistakes rather than operative errors. For example, in these 300 cases, 40 of the 54 major complications and four of the six deaths due

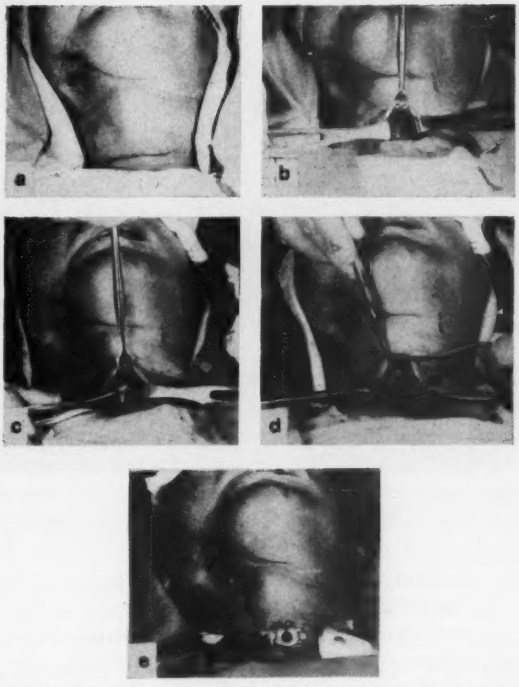

FIG. 23. Technic of elective tracheotomy (see Fig. 1). In *A*, the incision is marked. Note prominences of thyroid and cricoid cartilages. In *B*, the skin incision has been completed and the strap muscles separated in the midline to expose the thyroid isthmus. In *C*, the thyroid isthmus has been divided. The cricoid cartilage and first tracheal ring are visible. In *D*, a portion of the third tracheal ring has been excised. And in *E*, the cannula is in place.

to tracheotomy resulted from faulty postoperative management rather than from faulty operative technic.

There are three basic steps in aftercare necessary to keep the airway clear: (1) checking, cleaning, and changing the cannula as often as needed; (2) humidification of inspired air; and (3) proper aspiration of tracheobronchial secretions.

Improper fit or position of the cannula may be recognized by the unusual angle at which the tube rests, if the aspirating catheter consistently meets an obstruction, or if the patient has a persistent, irritating cough or recurring episodes of respiratory distress not relieved by aspiration. Most of these difficulties can be prevented by careful selection of the proper type, size, and length of the cannula at the time of surgery.[203] Special care should be taken in patients with swelling and distortion of the soft tissues of the neck from burns, infection, or neoplasms to avoid malposition of the cannula. Occasionally the skin incision or the incision in the trachea must be altered because of deviation of the trachea from adjacent masses.[23, 208] Malposition of the cannula may often be corrected by

packing with gauze around or under the wings of the cannula. In some cases, the cannula may have to be replaced.

Blockage of the cannula by mucus may be suspected if the patient has respiratory distress or noisy breathing which is not corrected by improved positioning of the cannula or by aspiration. Commonly, there is found a mucus crust which is attached to the end of the cannula and acts as a flap valve to produce recurring partial obstruction. Occasionally, crusts may be aspirated or coughed out by the patient or may be drawn out when the inner cannula is removed. Crusting is best prevented by adequate hydration of the patient, careful humidification of inspired air, the avoidance of dry oxygen administered directly into the trachea and constant removal of secretions so that these do not accumulate and become dried. The removal of crusts is facilitated by heavily saturated aerosol mist administered directly over the tracheotomy opening, by flushing with saline or saline-penicillin mixture, or by the use of detergents such as Alevaire. On occasion persistent crusting may be effectively combatted by the use of crystalline enzyme trypsin instilled directly into the trachea. The solution recommended by Steigman and Scott[252] consists of a mixture of 250,000 units of trypsin, 1,000,000 units of aqueous penicillin, 60 mg. of phenylephedrine and 50 ml. of Sorenson's phosphate buffer solution (pH 7.1). This solution should be made up in small amounts and kept refrigerated when not in use. Three ml. of the solution is instilled and aspiration is performed 3 to 5 minutes later. The solution may also be given by nebulizer. The clinical experiences in the few patients in this series with severe crusting has shown that the mucolytic and digestive properties of trypsin are of great advantage in promoting an airway free of inspissated secretions. Trypsin apparently liquefies this material readily without increasing the volume of secretions or causing local reaction, which are the two chief disadvantages of using streptokinase-streptodornase solutions.[158] If large crusts persist or if aeration is not gained by the above measures, then bronchoscopy should be performed without hesitation.[50, 60]

Proper aspiration of the tracheobronchial secretions involves more than just the insertion of a catheter into the tracheotomy cannula. The most common mistakes noted in this series of patients were inadequate aspiration due to a fear of inserting the catheter too far, the use of unsterile and nonhygienic aspirating equipment, overvigorous punching of the catheter into the trachea and bronchi, and the prolonged use of intense suction. In most instances the tracheal catheter should be inserted as far as it will go easily and deep enough to stimulate coughing. Suction should be applied intermittently as the catheter is slowly withdrawn. If further aspiration is needed the patient should be allowed to rest for a few breaths before the procedure is repeated. The aspirating catheter should have one opening at the tip which is beveled at about a 45° angle to avoid sticking of the respiratory mucosa in the catheter opening. There should be a side vent in the tube system so as to provide intermittent suction as desired (figure 24). The cannula may be shifted and the patient's head turned from side to side so that the aspirating catheter may be delivered into either main stem bronchus. As pointed out by Conley,[60] the insertion of a dirty aspirating catheter, which has

FIG. 24. Suction apparatus for intratracheal aspiration. Note the catheter with beveled tip and the Y-tipped glass connection for make and break suction. The catheter and irrigating solution should be kept sterile.

been handled freely, dragged over the bed clothes, and bathed in contaminated irrigating solution, unquestionably may lead to local infection, destruction of epithelium, purulent exudate, and scab formation. In addition, if the catheter is too vigorously inserted then bleeding and further obstruction from blood clots is promoted. The recommended equipment for aspiration is shown in figure 24.

Prolonged or intense aspiration may be a definite hazard to the patient because of a precipitous lowering of oxygen saturation.[157] This is especially true if there is marginal ability to ventilate or cerebral damage present. This factor was tested in four comatose, terminal patients with incurable disease. The ear oximeter (Oxyhemograph, Photocon Research Foundation, Pasadena, California) was attached and standardized to 100 per cent oxygen saturation for the individual patient. Relative, not actual saturation, was measured. After 5 to 10 seconds of continuous, intense intratracheal aspiration, the oxygen saturation began a rather sharp decrease, and after 10 to 15 seconds, saturation was reduced to below 85 per cent of normal. The patient was *cyanotic* at this point in most tests. It then required from 30 to 60 seconds for the oxygen saturation to return completely to normal. A representative tracing is shown in figure 25.

It was discovered that nonprofessional but well-trained assistants, under close supervision and after proper instruction, became quite adept at clearing the airway of secretions using the tracheotomy opening. If a tracheotomy cannula was in place, these assistants not only could more easily recognize that the airway needed cleansing, but also could more efficiently treat this condition than by using any other method. However, this does not mean that a lax attitude can be taken towards the aftercare of a tracheotomized patient. Indeed, since most of

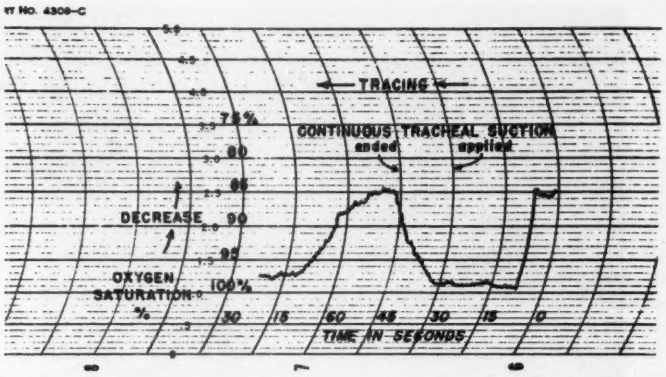

FIG. 25. Tracing of oxygen saturation using ear oximeter during prolonged intratracheal aspiration. Note decrease of saturation to 85 per cent of patient's normal after 10 to 15 seconds of continuous aspiration and slow return to normal over next 30 seconds. Tracing reads from right to left and a decrease of saturation is denoted by an upward swing of the recording needle.

the difficulties in management of these patients were the result of faulty aftercare, more careful attention to the principles just outlined for keeping the airway clear is recommended.

Complications

It has been stressed many times that a correctly performed tracheotomy is a harmless procedure and carries little additional risk for patients in danger of dying from asphyxia.[88, 90, 133, 134, 147, 222, 273, 275] In the few reports of larger series of patients in which deaths and complications are tabulated the fatality rate following tracheotomy ranges from 4 to 6 per cent.[66, 89, 90] The incidence of complications reported in these series is quite variable and depends largely on the frequency of emergency operations. The complications reported are generally accepted as a necessary part of an operation so often undertaken in haste and to save life. Despite the fact that fully one-third of the 310 operations under present consideration were performed under urgent conditions, and the fatality rate and incidence of complications were comparatively low in this group of patients, many of these errors and deaths were largely avoidable.

There were 16 deaths and 54 complications that were closely related to the performance or aftercare of these 310 operations (table 6). Ten deaths were due to errors of surgical judgment, mainly delay in taking prompt action when tracheotomy was urgently indicated. Six deaths were the result of errors in technic or aftercare. The case fatality rate due solely to the operation was 5 per cent and the incidence of complications was 17 per cent. No attempt was made to evaluate such complications as bronchitis, pneumonia, or atelectasis, since these were frequently present prior to operation.

The complications of emergency and urgent tracheotomy numbered over five times those of elective operations, although elective operations outnumbered the

TABLE 6

Complications and deaths occurring during and after 310 tracheotomies (1947–1955)

Complication	Number	Number of Deaths
Blockage of cannula	10	1
Bleeding	10	
During surgery (5)		
After surgery (5)		
Pneumothorax	7	1
Mediastinal emphysema	6	
Technical difficulties	5	1
Difficulty with cannula	7	2
Too low (3)		
Too short (2)		
Too small (2)		
Too long (1)		
Apnea	3	1
Aspiration of vomitus	2	
Wound infection	2	
Persistence of fistula	1	
Esophageal injury	1	
Total	54	6
Deaths due to errors of judgment		10
Total deaths due to tracheotomy		16

others almost two to one. Of the 54 complications, 14 occurred in patients less than seven years of age, although this age group represented just over 10 per cent of the total patients. These figures point out the increased danger of an emergency operation in the young.

Bleeding from the tracheotomy wound occurred five times during surgery in sufficient amount to be considered unusual and five times following surgery. In no instance was hemorrhage alarming or not easily controlled. In every patient bleeding came from the thyroid gland or vessels of the neck rather than from the tracheal lumen.

Crusting of mucus with blockage of the tracheobronchial tree or tracheotomy cannula was of serious importance in 10 patients and resulted in the death of one of these (figure 7). In this latter patient, access to the airway was denied for the previous 36 hours while continuous artificial respiration was given through an endotracheal tube. In four other patients bronchoscopy was necessary to remove adherent plugs and crusts of mucus and secretions.

Pneumothorax occurred in seven patients and mediastinal emphysema occurred without pneumothorax in six patients (figure 7). Mediastinal emphysema was not of clinical significance, since it produced no symptoms and was discovered mainly on chest roentgenograms. The theories that have been advanced to explain the development of pneumothorax in association with tracheotomy

include: (1) injury to the pleura, (2) rupture of alveolar sacs due to extreme elevation of intrapulmonary pressure, and (3) the passage of air by way of the cervical fascial planes into the mediastinum, with later rupture of the mediastinal pleura.[66] This latter explanation seems more plausible[84, 235] and is substantiated by the clinical picture in these seven patients. Every patient who developed mediastinal emphysema or pneumothorax was exerting strenuous respiratory efforts during the operation, and there was ample opportunity for air to be drawn into the mediastinum because of high negative intrathoracic pressure during inspiration. Roentgenograms of the chest failed to show pneumothorax or mediastinal emphysema in any of these patients prior to tracheotomy. This finding would seem to preclude rupture of emphysematous blebs or alveolar sacs as an explanation. Pneumothorax was more common in children, while mediastinal emphysema alone was more frequent in adults. This finding would indicate that in children the mediastinal pleura is more easily ruptured, or that the cervical fascial planes are more easily opened so that a proportionately larger amount of air could find entrance in the mediastinum. No patient in whom a bronchoscope or other airway was provided before operation developed pneumothorax. This would indicate that a decrease of respiratory effort is a definite factor in lessening the incidence of pneumothorax.

The incidence of pneumothorax (2 per cent) in this patient group was less than that previously reported.[89, 92, 93, 112, 201] This decrease is believed to be a reflection of two main factors: (1) the frequent use of the bronchoscope as a preoperative airway in children with mechanical airway obstruction, and (2) the large number of patients who either had no respiratory distress or, by virtue of their primary disease, were unable to exert marked respiratory efforts during tracheotomy.

A badly placed or badly fitted cannula was responsible for difficulties in the postoperative management of seven patients and was the cause of death in two of these. These errors included placement of the cannula at a level too low for use with the tank respirator (figure 7) and using cannulas that were too short, too long, or too small. Of the two deaths, one was the result of a short cannula which slipped out of the trachea and resulted in sudden asphyxia (figure 8), and the other was the result of a long cannula which eroded the tracheal carina and produced mediastinitis (figure 7).

Undue prolongation of the operation in five patients resulted from the presence of a tumor mass, infection, or a deviated trachea. One of these patients died during the operation. Another had such marked deviation of the trachea that the incision into the airway was misplaced badly and caused improper function of the cannula (figure 7). Other complications included apnea following tracheotomy, aspiration of vomitus, esophageal injury, wound infection, and a persistent tracheotomy fistula after removal of the tube. Difficulty in decannulation or chronic laryngeal stenosis were not encountered.

Results

Several pertinent and important conclusions were reached from the summation of results in these 310 tracheotomies (table 7). The case fatality rate of patients

TABLE 7

Results in 300 patients undergoing tracheotomy (1947–1955)

	Total	Lived	Died	Case Fatality Rate
A. Patients				
With MVO*	140	117	23	16
With SVO†	160	69	91	57
Total	300	186	114	38

	Total	Tracheotomy Deaths	Operative Fatality Rate
B. Operations			
For MVO	148	10	7
For SVO	162	6	4
Total	310	16	5

C. Patients with MVO saved by tracheotomy	45
Patients with SVO saved by tracheotomy	37
Total	82
Deaths caused by tracheotomy	16
Ratio of saved to died	82:16 or 5 to 1

* MVO = Mechanical ventilatory obstruction.
† SVO = Secretional ventilatory obstruction.

with diseases associated with secretional ventilatory obstruction was more than three times that for patients with mechanical ventilatory obstruction. This finding demonstrates that the diseases for which the value of tracheotomy has been recently recognized have an intrinsically high mortality. However, it was estimated that approximately 37 patients with secretional obstruction had their lives saved by tracheotomy. Without the operation the expected case fatality rate would have been nearer 80 per cent instead of 57 per cent. In patients with mechanical ventilatory obstruction an estimated 45 lives were saved by tracheotomy, and without the operation the case fatality rate would have ranged nearer 50 per cent. Of the total of 186 patients who lived, 82 survived mainly because of tracheotomy. This figure represents only lifesaving operations and does not include patients who had to have tracheotomy because of a laryngectomy, nor does it include the many patients who were benefited by tracheotomy used for anesthesia, postoperative care, and prophylaxis against respiratory obstruction.

The 16 deaths associated with tracheotomy includes 10 patients who died because the operation was too long delayed. This figure rarely is included in mortality statistics, since it introduces a factor which is difficult to evaluate—surgical judgment. However, the clinical records clearly indicated that about 3

per cent of patients died because tracheotomy was deferred in the face of positive indications for the operation. An additional 2 per cent of patients had a fatal outcome because of errors in technic and aftercare. This latter figure represents a relatively low mortality when compared with other series.[66, 89, 90] The majority of operative fatalities occurred in association with tracheotomy performed for mechanical airway obstruction and occurred during the earlier years of the period of this survey. A slight, but definite improvement in tracheotomy fatality has been in evidence in more recent years.

Certain of these conclusions are, of necessity, based on opinion rather than on proved fact. However, it should be pointed out that every clinical and autopsy record was carefully analyzed with the view in mind of determining a direct relationship of tracheotomy to either survival or death. Analysis of these statistics reveals that at least fives times as many patients survived because of the operation than died from it. In addition, 82 patients, or 27 per cent of the total number, owed their lives to tracheotomy. Every effort was made to avoid statistical favoritism for the operation. All the errors, complications, and deaths due to tracheotomy were tabulated without regard to mitigating circumstances or the serious nature of the patient's disease. Even with the operation presented in its worst possible light, the disadvantages of tracheotomy do, in truth, seem negligible when compared to the advantages of the operation in saving life, reducing morbidity, and improving over-all management of the seriously ill patient.

Summary of Clinical Material and Conclusions

1. An analysis of the indications, advantages, special uses, technic, complications, and results of 310 tracheotomies, performed in 300 patients, was undertaken. This is the largest such series yet reported that includes mixed indications for the operation.

2. This analysis revealed that there is not only an over-all increased use of the operation, but also that there are many new indications and uses for tracheotomy. In recent years tracheotomy is being used more for relief of secretional obstruction and for physiologic advantages than for its classical indication of bypassing a mechanical obstruction of the upper airway. Mechanical ventilatory obstruction is no longer the chief reason for tracheotomy and involvement of the larynx or adjacent structures is no longer the principal site of diseases necessitating the operation.

3. In addition to the time-honored and newer indications for tracheotomy, certain other uses for tracheotomy, that have not been widely stressed, were uncovered. These include the following: in severe burns and spinal cord injuries; in thoracic surgery as a vent to prevent closed glottis pressure postoperatively on a precarious bronchial stump closure; for positive pressure therapy of pulmonary edema; and for both emergency and prolonged respiratory resuscitation. The tracheotomy opening provided a simple, safe, and accessible route for endotracheal anesthesia, bronchoscopy, aerosol medication, and inhalation of oxygen.

4. Briefly stated, the advantages of tracheotomy in both mechanical and

secretional airway obstruction were as follows: mechanical, to bypass an obstruction and to remove secretions; physiologic, to decrease respiratory dead space, to decrease resistance to breathing, and for use as a vent.

5. A decided preference was noted for the classic technic of tracheotomy using a vertical skin incision and vertical incision into the trachea. Several disadvantages, hazards, and at least one death could be attributed to this technic. The advocated technic, based on personal experience and both clinical and experimental evidence, consists of a transverse skin incision, division of the thyroid isthmus, and excision of a portion of the anterior tracheal wall. Certainly none of these technical variations alone is new, but the inclusion of all three into one technic, as far as can be determined, is original. It was determined at autopsy and on experimental animals that it takes up to five days for a tracheotomy fistula to form. During this time, which is generally the most critical period for the patient with a tracheotomy, there is a distinct hazard of asphyxia should the cannula become dislodged or need replacement. The excision technic with division of the thyroid isthmus provides a safe airway if the cannula should become displaced or if it needs to be replaced by another cannula, bronchoscope, or endotracheal tube. No complications or delay in healing resulted from this technic. For emergency tracheotomy, the "feel" technic, as originally described by Chevalier Jackson, is advocated. The most common operative mistake made in this series of operations was the loss of valuable time by the surgeon in trying to visualize the trachea during emergency tracheotomy. Using the "feel" technic, the operation can, as intended by Jackson, be completed in less than one minute. Since visual exposure is not necessary, either a vertical or transverse skin incision may be used. The operation of cricothyroidotomy was not used once in this series of 310 tracheotomies.

6. The most frequent complications of tracheotomy were bleeding from the wound, crusting of secretions, difficulties with the cannula, pneumothorax, and technical difficulties at the time of surgery. Other complications noted were apnea after the operation, injury to the esophagus, wound infection, and a persistent tracheotomy fistula after removal of the cannula. Complications were more frequent in children and with emergency operations, and more often occurred postoperatively than during the operation. Six deaths resulted from the complications of tracheotomy, while 10 deaths resulted from delay in performing a clearly indicated operation. These 10 deaths bring to mind the axiom that *the time to perform a tracheotomy is when one first thinks that the operation might be indicated.* A certain frequency of complications and deaths is generally accepted as inevitable since tracheotomy is so frequently undertaken in haste and to save life. Despite the fact that the complications and deaths due to tracheotomy were quite low in this patient group, it was evident that most of these errors were avoidable. The excision technic, early tracheotomy before emergencies occur, the use of an airway to convert urgent operations to deliberate ones, the performance of emergency tracheotomy with dispatch when indicated, and careful attention to the details of proper aftercare are all positive steps that can be taken to reduce complications and deaths due to tracheotomy.

7. Over one-fourth of these 300 patients could be said to owe their lives to the operation of tracheotomy. This consideration alone, which disregards the special uses and advantages of tracheotomy in reducing morbidity and increasing the over-all efficiency of management, is ample justification for the present-day widespread use of the operation.

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